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GOOS Coastal Module Planning Workshop Report

prepared by the Scientific Committee on Oceanic Research of ICSU for J-GOOS

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Karl Banse, 1995.

"A century from now humanity will live in a managed - or mismanaged - global garden" (Steele et al., 1989). Presently, we worry about what to do about over fishing, ponder possible sub-lethal effect of oil or sewage discharge into the coastal oceans, and are scared by red and brown tides; we discuss the necessity to save some of the tropical forests; we are beginning to control emission of "greenhouse gases" into the atmosphere; and we struggle to calculate how fast and how much the climate will become warmer with and without such controls. A century from now these separate concerns will have been integrated into a single management system because of objective needs, but perhaps also because of broad intolerance of the mismanagement of nature. Obviously, the running of such a controlled system will require massive, continuous data-collecting or monitoring, which will presumably be largely automated. Our great-grandchildren, therefore, will live on a "wired earth" (Steele et al., 1989). Using the data so gathered, however, will demand massive improvements in scientific concepts, and this improvement is already the task for the present generation.

EXECUTIVE SUMMARY

The Coastal GOOS Workshop was convened in accordance with a recommendation of the third session of the Joint Scientific and Technical Committee for the Global Ocean Observing System (J-GOOS), and was chaired by Dr. N.C. Flemming (UK). The participants prepared for the meeting with extensive correspondence in advance to agree on general principles and objectives. This report sets out the economic and environmental arguments for the importance of the coastal component of GOOS, and shows that successful management and prediction of processes in the coastal zone depends upon analyzing maritime factors at a series of nested scales from the global to the local. Data are also required on a routine basis defining terrestrial inputs, and atmospheric processes and inputs.

J-GOOS-III (April 1996) discussed the development of the Coastal Module of GOOS, using the ongoing HOTO (Health of the Ocean), OPC (Ocean Processes and Climate) and LMR (Living Marine Resources) activities as models (J-GOOS-III, para. 6.3). The J-GOOS-III meeting was preceded by a one-day discussion on the Coastal Module. J-GOOS-III reported: "The key over-arching objective and product of the Coastal Module Design would be to provide a basis, in models and observations, for extended predictability of the coastal environment. This extension would aim at forecasts of more variables, with improved accuracy, and with the capability to predict ahead in time. One objective in this approach would be to provide a model product that would stimulate local development of observational systems for initialization and verification of a model relevant to the local environment." In general this text provided an accurate precursor of the topics which provided the most useful discussion and analysis during the Workshop.

The Committee decided in April 1996 to endorse the proposal for a Coastal Module Workshop later in the year. The Workshop should work toward an integrated observation system design for the coastal module; the Workshop should also consider a strategy for a generic modeling component. In the event, this workshop, which could not be convened until February 1997, took place at the Rosenstiel School of Marine and Atmospheric Sciences of the University of Miami. The task to be carried out by the Workshop included the original brief from J-GOOS-III, plus the specific request that the Workshop recommend to J-GOOS the next steps in the design of the Coastal Module of GOOS.

Activities which use environmental data and forecasts in the coastal zone include fisheries, aquaculture, coastal construction and development, hazard and disaster mitigation, search and rescue, waste management, monitoring harmful algal blooms, pollution control, tourism and recreation, shipping and port management, efficiency of offshore industries, and conservation of the natural environment, coastal defense and flood prevention.

The Workshop considered in broad terms the core variables which need to be measured and modeled in order to provide services which will support these customer activities, and produce social, environmental, and scientific benefits. It is recognized that each variable needs to be measured with a specified accuracy, and spatial and temporal resolution and sampling pattern.

The Workshop made no attempt to define these details, but referred to other expert groups, panels, and scientific programmes.

Data and information services in the coastal zone must be based on an end-to-end system of observations, data transmission, data quality control, data processing including modeling, archiving, analysis and data product generation, and finally data distribution to users. For much of the activity in the coastal zone there is a need for real-time data processing and distribution. The optimum design of observing systems requires intensive study and experimentation. Forecasting services in the coastal zone require scientifically designed interfaces to models of the open ocean, leading to the concept of a hierarchy of nested models.

The technology required to measure the variables identified by the workshop as important is adequate for some, but not others. Technological research and development is still needed, especially in regard to chemical and biological variables. The Workshop considered satellite and airborne remote sensing, ship-borne instruments, and subsurface moored, drifting and propelled instruments. In almost every case, even where the technology is adequate to obtain some accurate data, further investment is needed to produce instruments which are more reliable, need less maintenance and last longer in the field, all at a reasonable cost. Where routine and repeated long-term measurements are essential, cost reduction and increased efficiency of instrumentation and data retrieval are necessary.

The benefits of GOOS, and especially of the coastal component of GOOS, must be available to all states. During the design and initial implementation of GOOS the procedures developed by UN Agencies and ICSU ensure that all countries can be involved. In order to participate fully in the implementation of GOOS, and in the utilization of benefits, many developing countries will require enhancement of their capacity. The organization of GOOS by the Sponsor Agencies and national bodies will include a strong element of technology transfer, aid, training, and data sharing.

The Workshop concluded that the coastal module of GOOS requires a global structure to provide economies of scale, proven technology and procedures, and widespread use of best practice, and that there are ubiquitous problems and processes which can be observed or managed in consistent ways globally. The Workshop recommends that a Co-ordination Panel be appointed to review the progress of actions needed to support the Coastal component, reporting to J-GOOS. A series of actions are recommended also, which may be carried out by the GOOS Support Office, by specially appointed groups of experts, by national agencies, by Regional Groups of GOOS, by consultants, or directly by the members of the Co-ordination Panel. The Workshop recommends a strong role for Regional Bodies within GOOS.

1.0 INTRODUCTION

The IOC/WMO/ICSU/UNEP Joint Scientific and Technical Committee for the Global Ocean Observing System (J-GOOS), at its third session, recommended that a workshop be convened to lay the basis for the planning of the coastal component of GOOS. This workshop took place at the University of Miami in February 1997 and was chaired by Dr. N.C. Flemming (UK).

The twenty workshop participants (see Annex 1) came from twelve countries and were selected, in many cases, for their involvement in coastal science, in regional GOOS initiatives and in other existing coastal monitoring efforts. A substantial amount of preparatory work was done in correspondence before the workshop and participants considered a large number of topics and questions in advance and at the meeting itself (see Agenda, Annex 2). The list of documents which were available at the workshop is given in Annex 3.

An explanation of the acronyms and abbreviations used in this report is given on the final page. Readers wishing to locate more information on GOOS, coastal GOOS and related activities may find the bibliography in Annex 5 and the list of World Wide Web Home Page sites provided in Annex 6 to be helpful starting points.

All participants made substantial contributions to this report of the meeting and many of them submitted written comments to the first draft of this report. Final editing was done by the Executive Director of SCOR, Elizabeth Gross.

2.0 RATIONALE FOR A COASTAL GOOS

Why Do We Need a Coastal Component of GOOS?

The coastal areas of the world's oceans are extremely important both for the natural resources and ecological communities they contain and as areas of concentrated human activities. It is here probably more than anywhere else in the major components of the global ecosystem that human activities are in serious conflict with maintenance of environmental quality. The coastal zone receives inputs from upland agricultural, industrial, and urban practices. Natural disasters in coastal regions such as severe storms and flooding have major impacts on human life and welfare. The coastal zone is an area of convergence of activities in urban centers such as shipping in major ports and wastes generated from domestic sources and by major industrial facilities.

Coastal areas are of immense importance for human habitation and economic activity. Over 50% of the world's population lives on the 3% of the earth's surface area that is defined as coastal. This population percentage is increasing and, if present trends continue, will exceed 70% by 2030, or more than 6 billion people, compared with less than 3 billion today. Most manufacturing and services economic activity occurs in this relatively small area considered coastal. For the United States, the 10% of the country that is in coastal areas is estimated to generate over one-third of the Gross National Product.

Human uses of the ocean are most intense in the coastal zone. One means of quantifying these uses is the economic value associated with various marine-related industries. Several countries including Australia, France, the UK, and the USA have compiled economic data on some of the coastal uses. Some examples can be provided by data from the USA (Culliton, NOAA, 1990; The American Association of Port Authorities; US Census Bureau):

- US coastal areas include the most rapidly growing and densely populated counties in the country. The population of Florida will increase by 226% between 1960 and 2010 - from 5 million to 16 million. Nationally, the increase will be almost 60%, from 80 to more than 127 million people.
- The great majority of the world's international commerce moves through coastal waters, with the annual value of such trade just for the United States estimated to be about $571 billion in 1994. Commercial port activities employed 1.5 million Americans in 1992.
- Offshore deposits account for a large and increasing fraction of the world's oil and gas production.
- Commercial fishing is generally concentrated in coastal areas where most of the exploitable stocks are found. About 90% of the world's biomass of fish and shellfish occurs in coastal waters. About 60% of the people in developing countries obtain the majority of their protein from fish.
- These waters are a focus for recreational activities such as boating, bathing, and fishing. For example, in the USA recreational fishing was estimated in the early 1990's to contribute $6.2 billion and recreational boating $17.1 billion annually to the economy.
- Coastal US states receive about 85% of all national tourism revenues.

Flemming (1994) presented an economic case for a Global Ocean Observing System (GOOS) with the following annual estimates in U.S. $:

- offshore oil and gas, $135 billion;
- expenditures for oil and gas rigs and platforms, $45 billion;
- global fisheries, $126 billion;
- maritime transport revenue, $173 billion;
- global marine tourism, $100 billion;
- sales of recreational boats, $20-30 billion;
- marine electronics, $10 billion;
- civil ship building, $10 billion.

These marine-related industries total more than $629 billion per year. Not included in these estimates are the costs of insurance industry in the coastal zone, costs related to waste management, to maintenance of ports and harbors, navigational safety, marine weather forecasting, marine mining, and coastal shoreline protection, maintenance, and development. The coastal element of GOOS can improve the efficiency and reduce the costs of many of these economic sectors.

Beyond the immense direct economic significance of coastal areas is their great value for ecological and aesthetic reasons. Coastal waters contain biologically productive, diverse ecosystems that provide vital habitat for many commercial and endangered species. Wetland and other shoreline areas are extremely important breeding and spawning areas for many species of fish and other organisms and yet globally over 50% of such areas have already undergone severe environmental degradation. Shoreline areas also take on critical roles as buffers between land and sea. They protect uplands from storms and flooding while at the same time serving as filters to remove pollutants and other materials transported from upland areas before they enter the coastal ocean.

Following preparatory work by the IOC from 1989 onwards, including through the Second World Climate Conference, the signatory parties to the UN Conference on Environment and Development in June 1992 agreed that a Global Ocean Observing System (GOOS) should be established to meet the needs of the diverse uses and interactions of humankind with the marine environment. Working through the IOC, WMO, UNEP, ICSU, and FAO member states have begun to define their requirements for GOOS. This report examines the issues related to the coastal aspects of GOOS. It builds upon previous considerations of the Health of the Oceans (HOTO) and the Living Marine Resources modules of GOOS. The work being done in formulating the EuroGOOS, the NEAR-GOOS, the U.S. coastal GOOS, and coastal GOOS activities in countries such as Australia, Brazil, India, and New Zealand during the past several years has also been useful in our considerations. We assume that there will be one GOOS; the presently defined “modules” provide a means of defining the requirements to meet various objectives. We also assume that the coastal component of GOOS will have widespread applications for nearly all coastal states. Coastal GOOS involves a large number of cross-cutting issues being considered by the five modules.

In addition to regional activities which are already formally linked to GOOS, the workshop received information on other well-established regional monitoring networks. These activities have also developed a wealth of experience upon which Coastal GOOS should build. A prime example of such an existing monitoring system is CARICOMP, a network of Carribean marine laboratories, parks and preserves which concentrates on Caribbean Coastal Marine Productivity and which was initially supported by UNESCO. CARICOMP might provide a focus for the development of a Coastal GOOS initiative in the Caribbean region. Others such specialized networks include the Global Coral Reef Monitoring Network and “the IOC-UNEP International Mussel Watch” and a mangrove initiative. Information on these and other similar activities is given in Annex 4.

This report is based upon the experience of the participants who represent agencies and organizations in many countries where operational and routine monitoring systems have already been established for some products in the coastal zone. Operational marine information services have been set up already by government agencies and commercial organizations in some parts of the world, and there is considerable experience that can guide future efforts.

Concerns about the deterioration in coastal environments and ecosystems and about resolving conflicts in uses of coastal resources have prompted many coastal states to develop integrated coastal area management programs. International efforts are underway to focus attention on the need to achieve sustainable management of coastal resources and to preserve marine biodiversity. The coastal component of GOOS will establish a common approach to making the required coastal ocean observations, to achieving intercomparability among separate efforts within a region and throughout the world, and to producing a set of products that meet user needs.

Several examples in which a coastal-based ocean observing system will have increasingly valuable benefits include evaluations of sea level variations, climate change and variability, assessments of trends in occurrences of harmful algal blooms and occurrences of oxygen depletion in coastal waters, and enhanced sustainability of coastal ecosystems such as coral reefs, mangroves, estuaries, barrier islands, and rocky shores.

At present there are many programs being conducted by countries around the world pertaining to coastal observations and assessments. These programs include the determination of sea level variations, the characterization of currents, the provision of marine meteorological forecasts and wave conditions to increase navigation safety, and marine environmental quality measurements. Additional value could be derived from these efforts if the present local and national efforts were more closely linked to provide regional and global consistency and for the compilation and exchange of data and information products.

The workshop participants identified and discussed a large number of concerns which are ubiquitous in the coastal regions of the world and require global assessments and responses.

By addressing these concerns in coastal environments on a global basis there is recognition of the universal nature of coastal physical, chemical, and biological processes, the trans-boundary character of marine problems, and the benefits that can be derived by employing a common set of standards, procedures, and information products.

World-Wide Coastal Zone Issues

- Sea level change
- Ecosystem deterioration including preservation of biodiversity, the protection of critical habitats such as mangrove forests and coral reefs, the protection of endangered species and the introduction of non-indigenous species to marine ecosystems.
- Eutrophication from nutrient inputs from the watersheds and airsheds affecting the coastal zone.
- Waste management in the coastal zone
- Harmful algal blooms.
- Threats to human health posed by marine disease vectors
- Mitigation of natural and human-augmented disasters such as major storms, flooding, and coastal erosion
- Over-exploitation of coastal fisheries and threats to artisinal fisheries
- Mariculture management
- Safe and efficient maritime transport including, port design and management, safety at sea, search and rescue operations, and responses to pollution caused by shipping accidents.
- Effective design and operation of industrial operations in the coastal zone.
- Reduction of the impacts in the coastal zone from non-point sources of pollution.
- Tourism and other recreational uses of the coastal zone.
- Threats to fresh water supplies from salt water intrusion in coastal areas.

The potential users and partners in implementing the coastal portion of GOOS include the shipping industry, the oil and gas industry, port and harbor authorities, commercial fisheries, mariculture operations, the re-insurance industry, the tourism and recreation industries, the governmental agencies that support the needs of these marine-related industries, coastal zone managers, regulatory agencies for coastal resources, and the marine science community.

There are strong economic arguments for the development of the coastal products and services in GOOS and they have broad application to virtually all coastal states. These products and services can maximize efficiency and safety of many industrial operations, and they can minimize the environmental impacts of these industries. Broad economic studies of the benefits which can accrue from GOOS as a whole have been carried out by the OECD (1994) and by EuroGOOS (1996). These economic benefits relate directly to the value of the coastal component of GOOS since the vast majority of maritime operations are in the coastal zone, or within a few hundred kilometers of the shore. There are needs to minimize environmental damage, protect human safety and health, and preserve the value of marine resources. These efforts must be based on adequate environmental data, understanding, and information. The governmental agencies that provide these services are important potential customers of the coastal information products generated by GOOS.

GOOS has the objective to measure characteristics of the world ocean and coastal seas so as to produce data and products which have socioeconomic value and environmental benefits. This Report demonstrates that the greater part of these benefits will accrue by application of GOOS products to problems in the coastal zone.

3.0 COASTAL ENVIRONMENTS

Classification in the Coastal Zone

The coastal zone on a global scale is a highly variable environment physically, chemically, geologically and biologically. To facilitate a global synthesis of the coastal zone, clustering of types of coastal systems will be vital to enable GOOS to encompass the spatial and temporal heterogeneity of these systems. These groupings will need to be developed on the basis of natural and socio-economic features and processes.

These features and processes will need to include an extensive range of factors such as: geography (shelf width, shoreline configuration, bathymetry, etc.); catchment area and characteristics including land-use and freshwater runoff; sediment and nutrient inputs; rainfall; salinity; tidal range; currents; exchanges at the shelf edge; types of seasonal boundary conditions and degrees of seasonality; areal extent of important habitat types (mangroves, salt marshes, intertidal flats, reefs, macrophyte beds, banks, ledges, etc.); seabed sediment characteristics; levels of primary production; fisheries production and demographic and socio-economic characteristics. Any future classification of the coastal zone undertaken by GOOS should consider the coastal typology currently being developed by LOICZ.

The workshop participants identified a number of applications for GOOS in the coastal zone, the variables that may need to be measured in the context of GOOS, and the users with potential interests in the data, analyses, predictions and other products which would be generated by a coastal GOOS.

Table 1: examples of problems to be solved (or applications for GOOS) in the coastal zone, variables that need to be measured, and the "stakeholders" or end users of coastal GOOS data and products.

Applications	***Variables***	***End User***
Disaster Mitigation	Wind, Sea State, Waves, Storm Surges, Tsunamis, Sea Ice, Sea Fog	Local & central gov'ts Transport, Fishing companies Coastal residents & developers Insurance & construction cos.
Fishing	T, S, chlorophyll, Sea State, Currents, Population Biomass, Population Structure	Fishing companies
Mariculture	T, S, Sediment, Water Quality, Nutrients	Mariculture industry
Coastal Development	Wave Statistics, Sea Level, Sea-State, Erosion, Bathymetry, Sedimentation, Riverine Inputs	Design and Engineering cos. Local gov'ts, Insurance cos.
Waste Management	Currents, Winds, Biological and Chemical Variables, Dissolved Oxygen, Water Quality	Dumping companies, Waste producers, Local gov'ts
Harmful Algal Blooms	T, S, Currents, Winds, Species Composition, Nutrients, Rainfall, Continental Runoff, Solar Radiation	Fishery companies, Local gov'ts, Mariculture cos., Insurance cos., Tourism & recreation industry
Human Health Protection	bacteriological and chemical measurements in seafood, bacteriological indicators in seawater	Health departments and agencies
Pollution	Currents, Water Quality, Oxygen, Toxic Substances, Sediment Composition	Local gov'ts, Coastal developers, Construction industry, Coastal industries
Oil Spills	Currents, Winds, Waves, T, Ocean Color for Surface Slicks	Coast Guard, Clean-up operators, Insurance cos., Tanker cos.

Tourism and Recreation	Weather, Sea-state, Water Quality, Temperature, Solar Radiation, Rainfall	Tourism industry, Local gov'ts
Vessel Traffic	Currents, Winds, Waves, Visibility	Port Authorities, Shipping & Insurance companies
Efficiency of Offshore Operations	Sea State, sea level, currents, ice, sediment transport, wind, pollution parameters	Coastal Industries Offshore Oil companies Port authorities

Despite the highly variable nature of the coastal zone, there is a core set of variables that can be monitored and which are important and generic to all coastal systems (for example salinity, temperature, currents, tides, etc.). Other variables to be considered for a global monitoring programme will need to be stratified at the level of ecosystems (that is coral reef, mangroves, sandy beaches, etc.), or at the level of regional concern. A third level of stratification may be necessary at the local level to address locally identified problems or issues.

Scales And Interfaces in The Coastal Zone

This section considers the appropriate scales of observation required in the coastal component of GOOS, and the procedures needed to obtain the necessary data at the interfaces with the land, the atmosphere, and the open ocean.

The success of GOOS depends on routine and repeated observations from which, after suitable processing, useful information products can be generated. The temporal and spatial sampling pattern for any variable must be sufficiently fine to resolve the processes about which information is required. If the sample spacing is too coarse, some processes will be missed, and others aliased. If the sample spacing is too close, the observing system will cost more than necessary and will be inefficient.

The nesting of grids with different space scales has been used successfully in many modeling projects. For example, study of an estuary or a single coral atoll may be modeled using information from samples taken in grids spaced at 100m or less, over a distance of a few km to a few tens of km. This model may be nested within a model which is based on a coarser grid of samples, observations, or models, which cover an area of hundreds of km linear dimensions, with sample spacing of 0.5- 5.0 km. This model, in turn, can be nested within another model which covers a whole ocean basin, or even the globe. At each of the finer scales of observation, the outer spatial boundary conditions, and the longer term temporal processes, are defined, at least approximately, by the next larger scale.

Interfaces

For GOOS purposes, the coastal zone has a landward boundary at the highest level of tidal influence (HHWM) and at the point of continuous unidirectional downstream flow in watercourses. The seaward boundary, under most circumstances, is the continental shelf break. Exceptions to this definition of the seaward boundary might be in cases of islands having very narrow shelves, or of areas with high river discharges onto narrow shelves (e.g., the Amazon outflow). The precise definition of the landward boundary will depend on circumstances and on the nature of agreements between those involved in GTOS and GCOS planning.

It is accepted that the coastal zone receives inputs and forces from outside these margins, which are therefore its concern but not its domain. These inputs and forces are oceanic input from offshore oceans, terrestrial input from fluvial, artesian and groundwater sources, including modifications to these by human land use, and atmospheric forcing and transports. Oceanic influences in the coastal zone decline in magnitude towards the land (with the exclusion of tsunamis and storm surges), while terrestrial influences decline away from the land.

The variables and periodicity of coastal monitoring are determined by the existing understanding of the coastal system, and hypotheses proposed in explanation of existing problems. Economic activities in the coastal zone often require descriptions of the present state of the sea, or forecasts of processes and events a few days ahead. To make these predictions, measurements usually have to be made at intervals of a few hours. Understanding of global change in the coastal zone is best developed using physical variables such as those obtained from the Global Sea-Level Observing System of GLOSS. Global change of biological communities in the coastal zone is more difficult to detect. It is largely derived from two fields of research: ecophysiological studies that are rarely of more than a year's duration, and palaeoecological studies that can rarely resolve events within a 50 year time period. This time gap on the interannual/ decadal scale is filled by long-term monitoring, and would assist interpretations in both existing fields.

Scales

The coastal zone differs in width at different geographical locations. Island countries such as the Maldives and Kiribati have a large area of coastal zone relative to dry land, compared with continental countries. The width of continental coastal zones varies with gradient; Papua New Guinea being a good example: The south coast of PNG has a broad shelf that retains the large riverine sediment discharge of the Fly and Purari Rivers in coastal mangroves, while the north coast rivers of PNG, especially the Sepik River, discharge their dissolved and particulate loads directly into the surface layer over deep oceanic waters, with no appreciable shelf region.

Coastal zone forcing also varies in timescale. Sea surface elevation is a good example, varying on scales from seconds (waves) to daily (tides) to annual (steric effects), to interannual (e.g. ENSO) and longer term sea-level changes related to hydroisostacy, global climate and tectonics.

Detection of global change in the coastal zone requires long term monitoring of biological, chemical and physical parameters at many different locations. This approach allows separation and analysis of problems unique to a particular region from those with identified global trends. Global monitoring of this type has been attempted already in selected ecosystems. Some were discussed at the workshop and are described in Annex 4.

Periodicity of measurements

The periodicity of measurement is a function of the variability of the parameter, and the process that be understood in order to generate GOOS information products. Examples are given in the annexed section (Annex 4) on mangrove monitoring.

For efficiency and economy, it is best to optimize observations and maximize benefits from what is measured, and identify the variable and time frame for measurements related to particular coastal problems. Indirect methods of data production by means of numerical models can be incorporated with field measurements to produce detailed spatial and temporal variation.

Understanding of the time variability of such parameters should be tested from continuous monitoring of a reference area. This would allow reasonable interpolation of routine sampling.

Many coastal systems are greatly affected by high magnitude, low frequency events such as floods, cyclones or hurricanes. Such episodic events require adjustment of the monitoring system, such as higher frequency of physical parameter measurement during the event, and higher frequency of biological parameter measurement after the event to record recovery.

4.0 OVERALL SYSTEM DESIGN: PRODUCT GENERATION, DISTRIBUTION AND DELIVERY

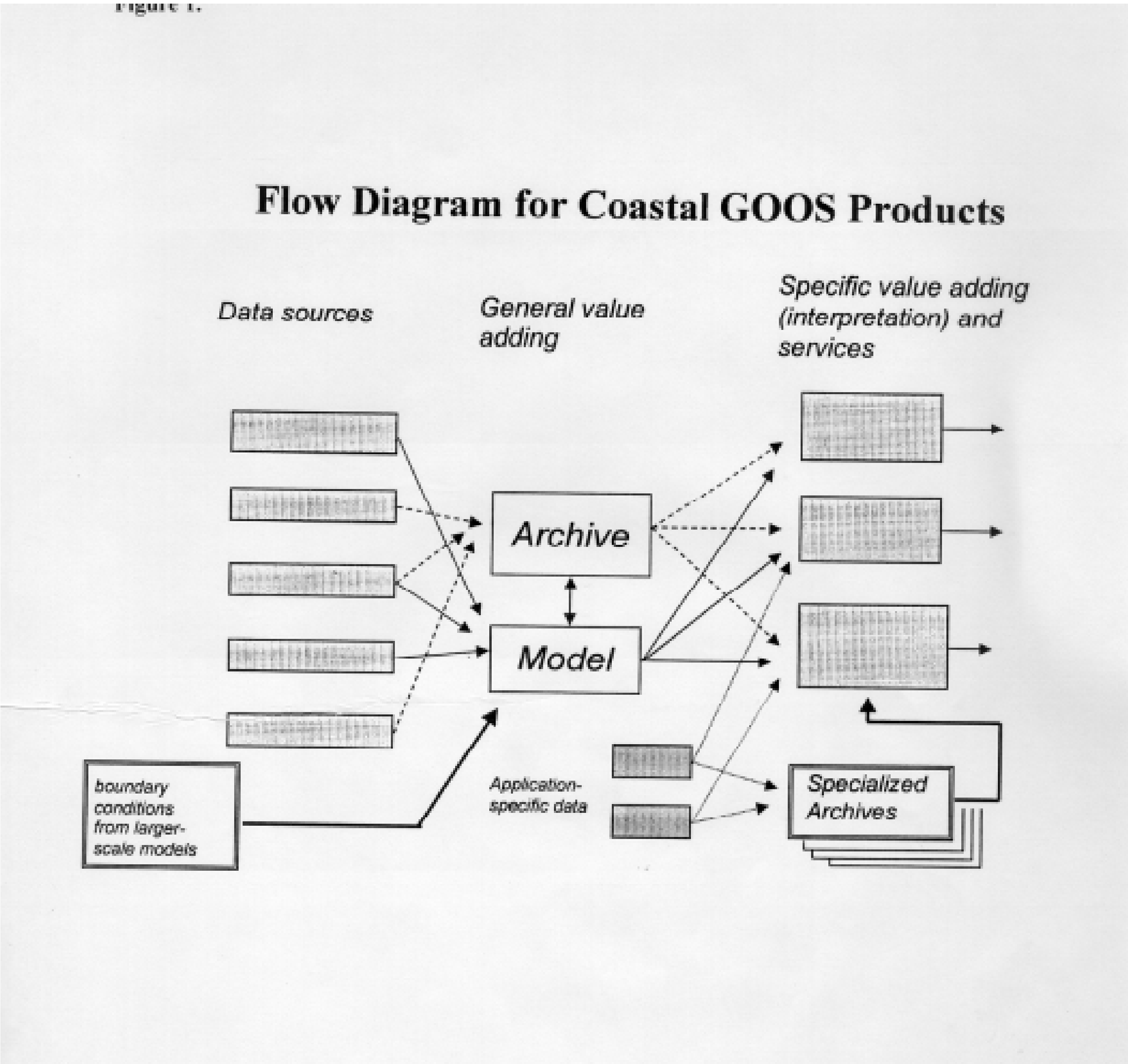
The overall system must be designed and implemented to provide the services which users require and are willing to support. This goal can only be achieved in concert with such users. The workshop participants identified a number of general problem areas in the coastal zone, the variables that may need to be measured in the context of GOOS, and the users with potential interests in the data, analyses, predictions and other products which would be generated by a coastal GOOS.

The individual components of the system must be fit for the purposes they serve in that system. A generic product generation and service delivery system of the kind required by the applications discussed in section is shown in Figure 1.

Data capture

It is a characteristic of measurements relevant to GOOS in general, and to the coastal zone in particular, that these measurements are of several types - physical, chemical and biological - and will be made by many different methods - *in situ*, by remote sensing from the ground, aircraft and

Figure 1.


Flow Diagram for Coastal GOOS Products
Data sources
General value adding
Specific value adding (interpretation) and services
Archive
Model
boundary conditions from larger-scale models
Application-specific data
Specialized Archives

satellites, in the field and in the laboratory, automatically and manually, by skilled scientists and technicians and by non-specialists. Nevertheless, there are some general principles which need to be followed.

Thus, the observing network design, in terms of the variables to be measured and their temporal and spatial resolution, must take account of the spectral characteristics of the variance to be expected and the purposes for which the data are required. The sampling strategy of a network monitoring sea level to determine tidal constants is obviously different from that required to detect long-term changes. An experiment or trial may be necessary to determine the optimum sampling strategy in particular cases. Sensitivity trials with numerical models - so-called Observing System Sensitivity Experiments (OSSEs) - can provide useful guidance for the design of observing networks. Furthermore, because data assimilation is capable of extracting the maximum possible useful information from a measurement, in routine use such models (even when used for analytical rather than prognostic purposes) can achieve substantial economies in the investment in measuring systems.

Data collection

When captured, data need to be brought to the point or points where they will be processed to generate higher level products. Again, there are many methods available and in use for this, ranging from telecommunications via satellite to the physical collection of paper-based records. As a general rule, it seems more economical to use well-supported commercial collection systems, when available, than methods which are specially designed for a particular site or problem. This is particularly so when there is a competitive market to spur innovation and hold down costs.

Data processing

Data processing is essentially of two kinds. The first is to generate an ordered database or archive of quality-controlled data, alongside (in some sense) similar data which are required in the provision of services. Typically, such data might be the pollutant loads as a function of time and space, information from a GIS, and physical data relating to the currents, temperature, salinity, winds, etc. for the same area and time. Such a database is the foundation of services requiring knowledge of past mean values, extremes, particular events and for analysis of variance with respect to position, state of tide, or meteorological conditions. Because GOOS monitoring is expected to be sustained, routine and long-term, it is important that the data archives include meta-data information, relating to changes in instrumentation and methods.

The second form of data processing employed in generating coastal GOOS services depends on the use of models. Such models may be numerical or statistical in nature. The former are based explicitly on the laws of physics, chemistry and biology, the latter are empirical.

As indicated above, deterministic numerical models are able to make very efficient use of measured data, because they add *a priori* knowledge in the form of those laws of nature. Where these laws include time dependance, such a numerical model has predictive capability. The results are inevitably limited by model resolution, the non-linear nature of modeled processes and the approximations made in representing the essential physics, chemistry and biology. Such models also require substantial computing capacity. In the context of the coastal zone, an effective methodology may be to run a high resolution (~1 km) model on the shelf which is "nested" within and obtains its boundary conditions from a coarser resolution open-ocean model.

It has proved possible to predict the evolution of some variables of concern to coastal GOOS by providing boundary conditions alone to a suitable numerical model - tides, waves, surges and some currents, for example. For other variables, assimilation of data throughout the temporal and spatial domain of the model is essential in some instances and generally adds value in others. By running such models from archive data - the so-called hindcast mode - it is possible to generate a range of statistics well beyond those resulting from measurement alone.

Statistical models employ empirical relationships to overcome the limitations in current understanding; they are much simpler and less demanding of computer resources than their numerical counterparts.

Numerical models also provide an effective method of quality controlling data. Differences between first guess predictions and observations provide a sensitive test - over a period of time - for biases, calibration drift and outliers.

Quality Assurance and Quality Control

To utilize data being gathered by ocean observation systems for developing useful products and services, quality control/quality assurance procedures for data gathering and analysis must be established and followed.

A QA/QC plan should be developed for each data type being

A "Coastal GOOS Deliverable" from Ocean Current Models

The core of an ocean model is the model software code simulating the hydrodynamical equations. These equations require that boundary conditions, initial conditions, and driving forces (wind fields, pressure fields, etc) are given for their solution.

If the modeling area is completely enclosed by land, the boundary conditions are trivial, otherwise, artificial boundary conditions apply. The nesting technique will provide more reliable boundary conditions for limited (coastal) areas.

Initial conditions are the difficult part, because observational coverage is inadequate, especially with regard to deep water density fields. The conventional way to "initialize" density fields is to use "climatological" monthly density fields, and allow only limited deviations produced by the model itself. In this way a "background" circulation is established, modified only by the varying meteorological driving forces.

These will be provided from operational meteorological modeling centers.

For a specific, limited coastal area, the conventional methodology is to use progressive nesting in order to use the proper spatial/temporal resolution. In this case, real time data assimilation may come into play, because current observations and temperature and salinity profiles could become available.

A local current map is a relevant product deliverable, e.g. to a vessel traffic service center overseeing vessels approaching ports or densely traveled ship lanes.

gathered as part of the Coastal GOOS observation network. Such plans should specify standards for short term accuracy and long term stability but not prescribe as mandatory the measurement methods to be employed - although the publication of recommended procedures and techniques is to be encouraged, *inter alia* to help capacity building. This approach is likely to increase participation in measurement programmes and encourages the use of improved methods as they are developed. The plans should include intercalibration (see the next section) and intercomparison exercises for each data type and methods of verification should be instituted. In this connection, numerical models provide an effective verification method. Differences between first guess predictions and observations provide a sensitive test - over a period of time - for biases, calibration drift and outliers.

User Integrated Products

The “modern seaport” is an analogy to the air control system to be found at every major airport. In air traffic control, relevant meteorological data are merged with traffic and navigational data, for obvious safety and efficiency reasons. A modern Vessel Traffic Service (VTS) system will contain the traffic image with maps of currents, winds and waves that can be shown on the same or separate screens. VTS operators require real-time data reflecting sudden and episodic events, as well as more prognostic phenomena such as current eddies.

Instrument Calibration

Many modern instruments have self-calibration capabilities in the form of software. Nevertheless, sensors and instrument packages tend to drift off calibration after prolonged shelf storage, or during use at sea. In particular, sensors for chemical constituents in sea water are usually only accurate for a few weeks or months at the most. All instruments used in routine observations should be calibrated to agreed levels before use. If the instruments are operated in drifting buoys, or are or disposable, the degradation of performance with time should be known. If the instruments are recovered or re-used, they should be re-calibrated at regular intervals. This is an important issue for consideration for all groups involved in GOOS planning whether in the industrialized nations or in developing countries. However, the lack of appropriate instrumentation and expertise makes this problem of calibration especially difficult to solve in the developing countries.

Information exchange

Real-time data exchange is not widely practiced amongst the oceanographic community. This capability will be essential for some applications, particularly those using data assimilation into numerical models. It will undoubtedly be efficient to set up necessary data collection and processing systems on a regional basis - as is being proposed in EuroGOOS, NEAR-GOOS and US-GOOS. Such arrangements provide substantial economies of scale and can avoid unnecessary duplication. However, efficient communication of data and products throughout the region is essential if all participants are to benefit equally from their joint investment. The Internet provides an effective method of accomplishing this. Even where the Internet itself is not the best carrier of the information, because of local unavailability or inadequate performance, the use of Internet protocols and standards is recommended. Such protocols are becoming *de facto* standards and allow access to a huge body of application software.

Service delivery

Service delivery must be responsive to user needs and be designed to be persuasive and achieve the necessary impact. In many cases the information provided will be only one input to end-user decision making and therefore must be delivered so as to allow presentation alongside other management data.

Services for Aquaculture

Harmful algal blooms can cause disruption of both wild and aquacultural fisheries operations either because of direct physical or chemical effects on fish or through the generation and transmission of toxins to human consumers of seafood. This appears to be a growing (i.e., more frequent and more geographically widespread) problem. Continuous long-term monitoring should provide a basis both for determining the conditions that lead to particular blooms and a predictive capability to ensure that protective measures are adopted in a timely and cost-effective manner. This offers considerable benefit to both the finfish and molluscan aquaculture industries which are frequently faced with major financial losses and hurriedly devised protection measures such as in the case of the outbreak of *Chrysochromulina polylepis* in Norway in 1988 when salmon pens had to be physically moved very rapidly in an attempt to prevent major fish mortalities.

Where the end-user is a regulator or legislator, information should be provided in a form which highlights departures from quiescent values and draws attention to significant trends, or unusual events, or extremes.

Whatever system is put in place, it should be capable of adaptation in the light of changing circumstances. The system should also contain procedures for assessing performance and methods of feeding back the results to correct deficiencies. Performance targets should be set and achievement against these monitored.

Pollution Prediction

Countries, both individually and regionally, frequently desire to know the scale and effects of contaminant discharge into coastal areas. What is discharged from the shores or into the rivers of countries does not constitute the final input to the deep ocean because of the sequestering of chemicals by particles, sedimentation and the production of authigenic compounds. It is possible, using physical and geochemical models, to determine the net efflux from estuaries, from the nearshore environment and, often, across the boundary between the coastal zone and the offshore deep ocean. Furthermore, such models and mass-balance techniques offer the value, in principle, of being able to determine if there are imbalances in fluxes that could reflect previously unrecognized sources of contaminants. Such techniques offer considerable benefits to countries adhering to, for example, the agreement on a Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities concluded in Washington, D.C. in November 1995.

5.0 WHAT VARIABLES SHOULD BE MEASURED IN THE COASTAL ZONE AND WHY ARE THEY NEEDED?

The following Tables 2, 3, and 4 depict the relevance of individual variables to Industrial Sectors, Environmental Issues of Concern and the provisions of International Agreements, respectively. The procedure for producing these tables was as follows:

- itemize in rows the variables potentially relevant to coastal zone characterization. This is done, for some variables , at two levels (as indicated in the two left hand columns);

- identify and enter in columns (Table 2) industrial sectors potentially having interests in coastal zone conditions or otherwise involved in maritime activities;

- identify and enter in columns (Table 3) environmental protection issues that are at the fore in current global negotiations and agreements;

- itemize and enter in columns (Table 4) contemporary international agreements dealing with activities in the marine environment or matters of marine environmental protection;

- the next step is to indicate where a particular variable is specifically relevant to the requirements of any of the sectors, issues or agreements in the columns of the tables. This has been done by placing a vertical caret [**^**] sign in the relevant cell;

- a further step has been taken by introducing a less-than [**<**] sign in instances where the sector, issue or activities covered by an agreement impose an influence on the variable. For example, many industries discharge contaminants or suspended matter to the coastal environment and such instances have been indicated.

It should be possible, at some subsequent stage in this process, to identify and introduce as a third left hand column, variables that are derived from combinations of others (density, for example)

These tables represent a first step in the process of identifying the relevance of variables to multiple purposes. This, in turn, should enable the limiting requirements for accuracy, precision and temporal and spatial resolution for a given variable in a given location to be determined for satisfying the most stringent of the needs/purposes.

It should be noted that the similar relationships outlined in the HOTO Strategic Plan have only been indicated as a general component of these tables. Once the requirements of the Living Marine Resources Module have been specified, the individual variables and any additional sectors of demand will need to be incorporated into these tables.

Table 2

^ = variable relevant to topic or issue < = variable can be affected by this sector

The requirements of regulatory authorities on these industries have not been considered in these assignments and may impose additional needs for GOOS observations.

The requirements of regulatory authorities on these industries have not been considered in these assignments and may impose additional needs for GOOS observations.

VARIABLES	VARIABLES		INDUSTRY						SECTORS			
		Agriculture	Pulp/Paper/	Fisheries	Aquaculture	Offshore	Tourism	Mineral	Marine	Utilities	Waste	Coastal
			Forestry			Oil/Gas		Extraction	Transport		Management	Development
Wind Field								^	^	^		
Wave Height				^	^	^		^	^	^		^
Wave Period					^	^			^			^
Sea Level		^			^				^			^
Wet Precip.												
Dry Precip.												
Reflectance												
PAR												
Sea Ice												
Coastline Change		<^						^	^	^		<^
Depth Correl.												
Measurements	Salinity			^	^	<			^	^		
In Water	Temperature			^	^	^			^	<	^	^
Column	Current Speed		^	^	^	^		^	^	^	^	<^
	Current Direction		^	^	^		<^	^		^	^	
	Diss. Oxygen	<	<^	^	^	<	<			^	<	
	pH											
	Nitrate	<			^		<				<	
	Phosphate	<			^		<				<	
	Silicate					<					<	
	pCO2, Alkalinity											
	Susp. Sed. Conc.	<	<^		^	<	<^	<^			<	
	Susp. Sed. Comp.	<	<^			<						
Biomass	Phytopl. Density		<		^?		^				<	
	Phytopl. Prod'n.		<								<	
	Phytopl. Comp.		<									
	Zoopl. Numbers				^?							
	Zoopl. Species											
	Nuisance Species						^		<	^		
Bottom Sediment												
	Character	<	<^	^	^	^	^	<^		^	<	<
	Composition	<	<^	^	^	^		<^		^	<	<
Benthic Comm.												
	Species						^	<			<	<
	Numbers						^	<			<	<
Bathymetry				^		<^		<	^			
[CONTAMINANTS]		<^	<^	<^	<^	<	<^	<	<		<	<
Land-Based	Water											
Inputs	Solid Matter											
(Airshed, Fluvial												
Artesian)												

Table 3

^ = variable relevant to topic or issue √ = variable can be affected by this activity

VARIABLES	VARIABLES	ENVIRONMENTAL		PROTECTION			ISSUES				HUMAN HEALTH	LIVING RESOURCES
		Ecosystem Health - Biodiversity										
		Coral Reef Ecosystems	Wetlands incl. Mangroves	Spawning & Nursery Areas	Macrophyte Communities	Habitat Change	Genetic Change	Non-Indig. Species	Community Structure	Eutrophication HAB	(see HOTO)	(see LMR)
Wind Field												
Wave Height		√		^?	^?	^?						
Wave Period				^?	^?	^?						
Sea Level		^	^	^	^	^						
Wet Precip.												
Dry Precip.												
Reflectance		^										
PAR					^							
Sea Ice												
Coastline Change			^			^			^	^		
Depth	Salinity	^	^	^	^	^		^	^			
Correlated	Temperature	^	^	^	^	^		^	^			
Measurements	Current Speed		^		^	^						
in the	Current Direction		^		^	^						
Water Column	Diss. Oxygen	^				^	^	^		√		
	pH											
	Nitrate			^	^	^		^	^	^		
	Phosphate			^	^	^		^	^	^		
	Silicate					^				^		
	pCO2, Alkalinity											
	Susp. Sed. Conc.	^		^	^	^			^			
	Susp. Sed. Comp.					^						
Biomass	Phytopl. Density	^			√	^		^	^			
	Phytopl. Prod'n	^										
	Phytopl. Comp.											
	Zoopl. Numbers			^		^						
	Zoopl. Species			^		^			^			
	Nuisance Species			^								
Bottom												
Measurements												
Sedimentary	Character				^	^						
	Composition				^	^						
Benthic Comm.												
	Species	^										
	Numbers	^										
Bathymetry												
[CONTAMINANTS]		^	^	^		^	^		^	√		
(see HOTO)												
Land-Based												
Inputs												
Airshed, Fluvial,												
Artesian												

Table 4

^ = variable relevant to agreement   < = variable can be affected by activities under this agreement

VARIABLES		INTERNATIONAL CONVENTIONS AND AGREEMENTS								REGIONAL AGREEMENTS					
		GPA 1995	LC 1972	UNCLOS	BIODIVERSITY	FCCC	MARPOL 73/78	Other Agenda 21	Black Sea	Medit. Sea	Carib. Sea	Baltic	OSPAR	Gulf	Etc.
Wind Field															
Wave Height						^			^						
Wave Period						^			^						
Sea Level						^			^						
Wet Precip.						^									
Dry Precip.															
Reflectance															
PAR															
Sea Ice															
Coastline Change						^			^						
Depth Correlated Measurements in the Water Column	Salinity	^	^						^						
	Temperature		^						^						
	Current Speed		^						^						
	Current Direction		^						^						
	Diss. Oxygen	^	^						^						
	pH														
	Nitrate	^	^						^						
	Phosphate	^	^						^						
	Silicate	^	^						^						
	pCO2, Alkalinity														
	Susp. Sed. Conc.	^	^						^						
	Susp. Sed. Comp.	^	^						^						
Biomass	Phytopl. Density	^	^			^			^						
	Phytopl. Prod'n	^	^			^			^						
	Phytopl. Comp.	^	^			^			^						
	Zoopl. Numbers								^						
	Zoopl. Species								^						
Bottom Measurements Sedimentary	Character	^	^												
	Composition	^	^												
Benthic Comm'y	Species	^	^			^			^						
	Numbers	^	^			^			^						
Bathymetry			^						^						
[CONTAMINANTS] (see NOTE)		^	^?						^						
Land-Based Inputs (Airshed, Fluvial, Aeolian)	Water	^													
	Solid Matter	^													

6.0 TECHNOLOGY FOR COASTAL GOOS

To understand the phenomena which influence the coastal environment, habitats and processes, data on a wide range of aspects must be collected. Over the years a substantial progress has been made in the development of technology for measuring a variety of physical, chemical, biological and geomorphological parameters. This section identifies the technological basis for implementing the coastal component of GOOS.

Table 5: Proven technologies for continuous/automatic and *in situ* measurements and for routine monitoring.

Variable	***Instrument/System/Platform (Satellite/Buoy)***
Sea level / tides	tide gauges (pressure and acoustic), seabed echosounder (inverted echosounder) satellite altimeter
Meteorological variables, e.g.: air temperature, atmospheric pressure, humidity, wind velocity and direction, solar radiation	land-based observation and data collection platforms, buoys and observation towers with telemetry using VHF, HF and Satellites, ship-borne deck/bridge observations
Extent of sea ice	Synthetic Aperture Radar (SAR) Self Scanning Microwave Instrument (SSMI) and shore-based radar
Photosynthetically available radiation	*in situ* sensors
Wave period, height	wave rider buoys with telemetry, satellite based SAR
Wave direction, frequency spectra	shore-based radar, wave directional buoys with telemetry
Sea Surface temperature	*in situ* sensors, satellite radiometers, drifting buoys
Vertical profile of temperature	XBT
Vertical profile of salinity and temperature	CTD, XCTD
Surface currents	shore-based high frequency radars (e.g., OSCR, CODAR) wind-sea coupled models, ADCP, moored and drifting buoys
Vertical profile of currents	ADCP, current meters
Salinity	*in situ* sensors, discrete samples, buoy mounted sensors
Dissolved oxygen	*in situ* sensors, discrete samples, buoy mounted sensors
Ocean color (surface chlorophyll)	ocean color scanner
Turbidity and suspended sediments	*in situ* sensors, bottom mounted acoustic instruments, satellite optical sensors, moored buoys
Reflectance (oil spill detection)	satellite based radiometers
Precipitation	radar

Table 6: Proven technology and techniques which are used in the research mode, but are not yet in commercial production for routine, operational use, or are currently so labor intensive as to make them impractical for GOOS purposes without further development.

Variable	**Instrument/System/Platform (Satellite/Buoy)**
Bathymetry	single and multi-beam echosounders, side scan sonars, Hydrosweep
pH / CO_2 / alkalinity	potentiometric and optical sensors
Reflectance (oil spill detection)	thermal sensors, airplanes based SAR
Nitrate	*in situ* measurement techniques
Nutrients	spectrophotometer, auto-analyzer
Trace metals	atomic absorption spectrometer, inductively couples plasma emission spectrometer with mass spectrometer, chemiluminescent analyzers
Pesticide residues, polychlorinated hydrocarbons	gas chromatography, mass spectrometers
Petroleum hydrocarbons, chlorophyll	spectrofluorometer
Phytoplankton	discrete samples, automatic cell counters, taxonomic identification software, microscope analyses
Zooplankton	conventional counting methods, taxonomic identification, software, automated video system
Chlorophyll	satellite based ocean color scanner, compact air borne spectrometer, *in situ* fluorometer, discrete samples
Bacteria	culture methods, cell counters, flow cytometry
Primary productivity	14C technique with scintillation counters
Coastal maps showing habitat types - e.g., mangroves, mud flats, salt water lakes, coral reefs, shoreline changes	satellite imagery at various scales, aircraft mapping
Prediction of nearshore phenomena like circulation, sediment transport	numerical modeling techniques
Precipitation	shore-based stations

Technology Problems

During their discussions, the workshop participants identified a number of problems which must be addressed if currently available technology is to be widely deployed in support of a coastal GOOS.

Satellites - Satellite techniques provide large area and repetitive coverage. However, validation through ground and sea truthing is time consuming and laborious. Presently achievable resolution is inadequate for fine-scale mapping of critical areas. Further, non-availability of topo sheets, even at the 1:25,000 scale for validating satellite maps, discourages the utilization of satellite techniques for fine-scale mapping in many developing countries. In addition, there may be defense department restrictions on the preparation and utilization of maps for specific areas.

Data buoys - In many areas of the world, the security of data buoys is a serious problem. They are often the target of sabotage by fishers and others who do not understand that the buoys are being deployed in their interests.

The fouling of instruments and sensors on buoys is another problem which can require nearly constant attention, especially in tropical areas where they may become covered with sediment and fouling organisms within a few days of being deployed, rendering the data of doubtful quality.

The telemetry of buoy data via satellites is expensive. Alternatives, such as radio telemetry involve other problems. For example, VHF transmission requires a “line of sight” between the buoy and the receiving station, and HF often has problems with interference.

Data Compression

It is recommended that reconnaissance surveys be undertaken before planning any program of long-term measurements in a large area. The results obtained can be evaluated and areas of less significance can be avoided, while effort is concentrated in the most efficient manner. Advanced presentation techniques like the Geographical Information System (GIS) can also be used for graphical representation of large amounts of data. Transmitted data can be reduced in volume by the computation of statistics, spectra, the transmission only of extreme events, and other techniques.

Cost Reduction

Ship-based operations are expensive and need huge amounts of personnel time. Even so, there are severe limitations to the spatial coverage which can be achieved with ship surveys. Buoy-based measurements provide an alternative in terms of reduction in personnel time, but the costs of their operation remains high and they produce time series at points rather than sections along a track . Mounting of sensors for certain atmospheric and oceanic variables on navigational buoys in inshore waters may reduce such costs. This may also help to reduce losses due to sabotage since most people are aware of the importance of the navigational buoys to their safety.

Biological Systems

Clearly, the initial approach to the definition of the purpose and content of a coastal component of GOOS has concentrated on the main products and user community demand. This is largely the domain of physics, allowing for the existence of a strategy for environmental and human health protection measurements developed by the HOTO panel and the intended development of the Living Marine Resource component of GOOS by the LMR panel. This leads to a dominance of physical and oceanographic considerations over biological considerations such as the requirements for coral reef protection, mangrove protection and some aspects of biodiversity. Further consideration of these issues will be required. This will require a decision by J-GOOS as to the specific mechanism or Panel with which these topics will be considered with a view to developing a holistic strategic plan for a coastal zone component of GOOS.

Emerging Technologies

Development of chemical sensors for moored and drifting data buoys - The development of data buoys to overcome time-consuming ship-based observations for certain chemical variables like nutrients, petroleum hydrocarbons and trace metals has been receiving the attention of technologists in recent years. A few prototypes are already available in the market, and they are being tested for their accuracy and reliability. Most of the chemical sensors developed to date measure concentrations at the level of parts per million. More research is necessary to achieve increased accuracy and sensitivity, say to levels of parts per billion, as required to detect certain contaminants.

Remotely Operated Vehicles (ROVs) - Research and development efforts are being made to develop unmanned remotely operated vehicles equipped with sensors for measuring physical, chemical and biological parameters. A few prototypes have been developed. Such a technology will be very useful for coverage of large areas in a short period of time. It avoids the use of several sampling devices and should reduce the excessive requirement for research ships. This new technology may become commercially available within a few years.

Others - The workshop recognized that it did not have the expertise available to fully explore the potential of new technologies for GOOS. In addition to the two items discussed briefly above, other methods such as acoustic tomography and the use of pilot-less drone aircraft, to name only two, should be considered by J-GOOS.

9.0 CAPACITY BUILDING

The strategic design of the Coastal Zone component of GOOS needs to be developed from the perspective of ubiquitous global issues, concerns and required outputs/products. The needs for GOOS, and the benefits to be derived from it, are those enunciated by the international community in terms of economic and social development and environmental protection. These aspirations are partly reflected in multilateral agreements and international conference documents (e.g., Agenda 21).

The workshop noted that the coastal zone components of GOOS, initially developed in response to global issues, will subsequently need to be further developed and refined in the context of specific local/regional circumstances. Many problems in the coastal zone (e.g. eutrophication, habitat loss, storm surges) are especially severe in developing countries, although they may well have a global impact. Thus, in order for Coastal GOOS to be usefully implemented where it is arguably needed most, attention must be paid to the issues of training and capacity building

If the Coastal GOOS Module is realized in a global sense, and it is planned to be based on a global data acquisition network, all the world's coastal regions must be considered in detail, with their local, regional and global peculiarities. It is impractical to plan a network for data acquisition, processing, analysis and interpretation with any predetermined scales of temporal and spatial resolution on a global level. However, it is essential that the locally-implemented constituents of a global GOOS are consistent with a global perspective so as to achieve regular and comprehensive sampling. For the same reason, the local/regional methodologies used to obtain and to process the data and its quality control, must be of adequate precision and accuracy to meet global standards and requirements.

Once the standards are defined, mechanisms to assure the required network design must be considered.

These points apply particularly to developing countries, where the human resources for coastal studies are sparse or do not exist. To ensure a good world-wide coverage, this problem must be corrected. The other point that must be considered is related to the technology that would be used for data collection, processing and analysis. Such technology must be accessible to all stakeholders, on a low cost basis and in an operational sense. Accordingly, assistance must be provided to help developing countries to raise the initial financial support required for the acquisition and deployment of the necessary devices in selected sites. Maintenance and calibration are other issues that must be considered when dealing with long term operation. For an efficient operation of such a system, a constant flux of technical and scientific knowledge and financial support is essential.

The gaps in the geographical distribution of coastal activities are especially severe in the Southern Hemisphere. Regional and National Coastal GOOS projects in these areas must be encouraged, promoting local groups to build their own local and regional programs, using installed capacity, where possible. On the other hand, strong effort must be applied in the area of education, promoting facilities for medium and high level scientific and technical education for national scientists of these countries. The implementation of a global observation network is only the first step, that will be followed by a long term operation and maintenance of the data acquisition systems. The necessity of well trained technical and scientific teams needs to be emphasized at all stages of the planning process.

The resulting data bases should be accessible to all participants, and Internet standards for data transmission must be established to facilitate data transfer. Products developed with such data bases should be accessible to all participating countries.

Practical solutions to these problems may be obtained through regional GOOS initiatives, particularly where a region includes both developed and developing countries. In addition, the natural teleconnections induced by oceanic and atmospheric dynamics mean that phenomena occurring in one region may have impacts on other very distant parts of the globe, regardless of national, political boundaries. This provides a rationale for training and capacity building being provided to the developing countries, even on the restricted basis of the self-interest of developed nations.

There is much "aid" which can be provided which costs the donor little but can be very valuable to the recipients in developing countries. Examples of this include:

- the provision of training in recipient countries
- the adoption of a free and open exchange data policy
- the release of historical data sets
- the free provision of products/advice in exchange for data from developing countries
- the encouragement, development and use of "consumer" technologies i.e. those that benefit from substantial markets
- assistance in the establishment of national and regional data centers
- major modeling centers can run models in domains of interest to developing countries particularly if such initiatives are accompanied by the provision of scholarships to allow recipient countries to participate in the generation and interpretation of model output.

10. CONCLUSIONS AND RECOMMENDATIONS

Preamble/ Conclusions

The Workshop did not have the brief to make technical recommendations for actions or priorities in establishing the coastal portions of GOOS. The participants analyzed what they considered to be the essential factors influencing the design and development of GOOS in the coastal zone, and the arguments which relate to the design of a system to generate coastal products. This report is based firmly on the experience of agencies in more than 20 countries, all of whom have several years of practical experience in the management of marine data, and the provision of routine services. The views in this report are offered by the workshop participants to be used as guidance by the organizations or bodies charged by J-GOOS to implement the Recommendations which follow.

The Workshop identified some of the issues, industrial and other user sectors which will be served by the data products of GOOS in the coastal zone and these are set out in Table 1.

Based on this set of applications, the Workshop agreed on a provisional list of variables which must be monitored in order to provide appropriate products to the managers of these applications (Tables 2, 3 and 4). It is noted that not all the variables in these tables are the provenance of GOOS, and some data types will be required from land-based agencies, or are being co-ordinated by GCOS or GTOS.

The Workshop has considered the technologies, defined the generic end-to-end system within which those technologies will be deployed, and suggested best practice in their use so as to provide reliable information services.

GOOS design, including the coastal component, is based on the evidence that there are real advantages in carrying out the design at a global level. This evidence includes:

- The understanding that there are ubiquitous processes which can be measured, modeled, and predicted.
- The commonality of problems and applications in the coastal zone. as perceived by customers and user groups.
- The recognition that there are global concerns related to global climate change, climate variability and other aspects of global environmental change, both naturally and anthropogenically induced.

Advantages include:

- Available technologies and communications which permit the assembly of synoptic or near synoptic global data sets.
- Economies of scale.
- Widespread application of best practice.
- Consistent and compatible data sets gathered by different groups permitting the creation of coherent global data sets.

These factors necessitate that GOOS be designed and implemented with full recognition of the need for coherence at the global scale. A future objective of J-GOOS must be to enure that an agreed set of core variables to be measured in coastal GOOS is defined. Wherever possible the coastal component of GOOS should include sets of core variables which are measured to compatible standards globally or within ecosystems, in addition to local and site-specific requirements. It is one of the duties of J-GOOS to oversee the achievement of this global coherence.

The Workshop considers that the resources, staff, skills, and experience necessary to start the implementation of GOOS in the coastal zone on a phased basis, and to carry out the necessary operational activities, including pre-operational research, do exist at the level of national agencies, and of the large national and regional GOOS programmes. The recommendations of this report are therefore balanced so as to retain the responsibility for global coherence and integration at the level of J-GOOS, while suggesting that the responsibility for detailed design and implementation is most appropriately delegated to the national and regional levels.

Recommendations

The Workshop recommended the formation of a GOOS Coastal Module Panel, but recognized that many of the recommended actions need not be initiated by or controlled directly by the Panel. Many of these necessary actions can be carried out by the GOOS Support Office, by Regional and National GOOS bodies, by groups of experts, or by consultants. The Panel should oversee and review such activities, without causing delays in urgently required actions. In particular, as regards the coastal zone, J-GOOS itself and the Panel must take into account the vigorous level of national and commercial activity which will proceed regardless of GOOS, and try to integrate these activities in the most efficient way possible.

The Workshop Recommends that J-GOOS should:

1. Form a GOOS Coastal Module Panel with the Terms of Reference set out in Annex 7.

2. Ensure that analysis is conducted showing in detail the full range of problems which occur in the coastal zone requiring GOOS services, the urgent issues and requirements for monitoring and information which are the driving reasons for the development of GOOS in the coastal zone, the user groups and categories of industries which are the potential customers, the products which they require, and the variables which need to be measured to deliver those products.

    2a. Facilitate the investigation and definition of sets of core variables appropriate at global and other scales or regimes including recommended degrees of accuracy and resolution.

3. Continue to assess the requirements identified by the other GOOS Modules in the coastal zone, and optimize their integration with the Coastal Module Panel.

4. Promote and encourage the conduct of economic studies in coastal regions to assess the benefits of GOOS regional products, especially in order to identify the services which will be most useful to developing countries.

5. Encourage regional GOOS groups to promote market research on the needs for GOOS coastal products, and establish links with global organizations representing major industries and services in the coastal zone who will be potential users or beneficiaries of GOOS products. Establish working relations with stakeholders in the coastal zone.

6. Encourage regional GOOS groups to develop GOOS Coastal activities which involve the Developing Countries as participants, and promote Capacity Building which will facilitate generation of GOOS products in the coastal zones of Developing Countries.

7. Promote and encourage the development of coastal environmental data services through regional collaboration between Member States and Agencies, and promote the formation of such regional associations in GOOS where appropriate.

8. Encourage the development and testing of new technologies which are designed to meet the requirements of the coastal component of GOOS.

9. The Workshop recommends the following regional initiatives to J-GOOS as initial steps to begin moving the Coastal Module of GOOS forward:

   (i) Endorse or recognize the entities with regional scope represented by NEAR-GOOS, EuroGOOS, and national initiatives such as India-GOOS and US-GOOS, as appropriate organizational mechanisms for meeting the needs of the coastal component of GOOS.

   (ii) Identify and encourage the formation of similar regional and national entities, and/or the expansion of the existing regional and national entities, in order to achieve the required global scope for the coastal component of GOOS. Examples of regions where Member States and Agencies might consider it appropriate to quickly expand the regional approach include the Black Sea, the Caribbean, the Mediterranean, the South Atlantic, the South China Sea, the Arctic and the South Pacific.

   (iii) Forward this Workshop Report to the existing regional and national entities to provide guidance on the needs of Coastal GOOS, requesting their feedback to the future planning process.

   (iv) Charge those entities with developing practical action plans relevant to the coastal requirements of their regions.

   (v) Review, and when appropriate, endorse those plans, as being scientifically and technically viable and consistent with GOOS objectives. J-GOOS should consider developing a procedure whereby regional plans can be reviewed and, if appropriate, given international endorsement by J-GOOS.

   (vi) Devise and encourage mechanisms for achieving an efficient overall plan for coastal GOOS drawing on the experience of the regional entities, which meets the needs of all GOOS Modules, and in coordination with the other global observing systems and the World Weather Watch.

10. Propose to the GOOS Support Office to establish procedures by which virtually all coastal states can become engaged in the process of designing and implementing the coastal portion of GOOS. These procedures should include the following:
    - incorporate into the GOOS World Wide Web site the list of contacts in each country for GOOS overall, and for the HOTO, LMR, Climate, and Coastal Modules of GOOS
    - incorporate links into the GOOS World Wide Web site links that point to national and regional GOOS planning efforts
    - encourage the dissemination of established and prototype GOOS information products via the World Wide Web.

CONCLUDING STATEMENT FROM THE GOOS COASTAL WORKSHOP

Coastal GOOS derives much of its justification from the increased effectiveness and efficiency with which economic activities can be carried out in the coastal zone. However, as recognized by Chapter 17 of Agenda 21 and elsewhere, important societal goals, such as those set out in treaties and conventions on climate change and biodiversity, and those relating to human health, will also be supported by a coastal GOOS.

There is no doubt that some valuable, albeit limited, progress can be achieved by the better use of existing resources. But, to the extent that governments and agencies wish to reap the benefits of Coastal GOOS and to fulfill their responsibilities identified under UNCED and other agreements of the global community, resources will have to be found for these purposes.

The benefits identified and the recommendations made above, have significance only in so far as the commitments of nations to support the GOOS initiatives are realized.

ANNEX I - List of Participants

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GOOS Coastal Module Planning Workshop

University of Miami, February 24-28 1997

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ANNEX II - Agenda

IOC/ICSU/WMO Joint Scientific and Technical Committee for the Global Ocean Observing System (J-GOOS)

GOOS Coastal Module Planning Workshop

University of Miami, February 24-28 1997

ANNOTATED AGENDA

MONDAY

0830 - Agenda Item 1. Welcome by Chairman J-GOOS. Participants introduce themselves, and their affiliation, round the table. Introduction of Members of the Secretariat.

0850 - Agenda Item 2. Summary of local arrangements, transport, who has hire cars, meal times, mechanism for expense claims, access to terminals for writing report, use of personal lap-tops, software compatibility.

0915 - Agenda Item 3. Check on receipt of documentation circulated from SCOR, IOC, SOC. Duplicates available if possible for missing documents. Review of new documents brought by participants.

0930 - Agenda Item 4. Report by Professor Otis Brown. Review of background of J-GOOS in setting up the Coastal Workshop. Requirements from the Workshop, results and scope of recommendations needed. Comparison with status of other Module Panels and Workshops. Possible changes of structure of GOOS arising from recent meeting of the Strategic Sub Committee. Suggested time-frame for future actions. Discussion.

1000 - Agenda Item 5. **PRESENTATIONS**

(Note: Presentations are assumed to take 15 minutes each.)

1010 - 1) Nic Flemming: Purpose of the workshop, objectives, and need to focus on end-product, report, and recommendations. Review of possible options. Definitions of opportunities and limits.

EXAMPLES OF NATIONAL OR REGIONAL COASTAL SURVEY SYSTEMS

1025 - 2) Joanna Ellison: Long term monitoring of tropical coastal systems by AIMS.

1040 - 3) Dong-Young Lee: Coastal service system established in Korea in the context of the North East Asia coastal environment.

1055-1120 Coffee Break

1120 - 4) Eduardo Marone: Coastal zone studies in the Paranagua Bay, Brazil.
1135 - 5) B.R. Subramanian: Indian coastal zone monitoring.
1150 - 6) Julie Hall: New Zealand coastal observation system.
1205 - 7) John Ogden: Long term monitoring of coastal ecosystems in Florida.

GOOS ORGANIZATION, MODULES, LOGISTICS

1210 - 8) Peter Ryder: The design and Planning of GOOS: The Role of the Coastal Module.

1225-1330: LUNCH

1330 - 9) Su Jilan: North East Asian Regional GOOS (NEAR-GOOS).
1345 - 10) Salvatore Arico: International guidelines on integrated coastal area management (ICM) for the integration of the ICM perspective into the Coastal Zone Module of GOOS.
1400 - 11) Nic Flemming: The EuroGOOS approach to integrating the coastal module with larger scales, regional and oceanic.
1415 - 12) Eric Lindstrom: US-Coastal Module of GOOS: the Three areas of Emphasis.
1430 - 13) Andy Robertson: US Co-ordination of GOOS, co-ordination and implementation activities.
1445 - 14) Neil Andersen: Report on the US Coastal GOOS Workshop on Sustainable Healthy Coasts, and division of the USA Coast into generic regions.
1500 - 15) Mike Bewers/ Neil Andersen: The role of the GOOS Health of the Ocean Module (HOTO); the linkage between HOTO, the Coastal Module, the open ocean, and the land.

1515-1530: Tea break, Discussion.

TECHNOLOGY AND SYSTEMS, SYSTEMATICS

1530 - 16) Johannes Guddal: Radar Ocean Sensing (ROSE), a tailored contribution to GOOS Coastal Module.
1545 - 16) Dana Kester: Satellite remote sensing and autonomous in situ sensors define the scales and causes of variability in coastal waters.
1600 - 17) Minoru Sasaki: Electronic navigation as part of an ocean and coastal observation system.
1615 - 18) Mark Luther: The PORTS real time oceanographic and meteorological system.
1630 - 19) Francisco Chavez: Interdisciplinary eastern boundary ocean observing systems: What they should look like.

1645-1730 Discussion of presentations, factors to be taken from the presentations for the Report. Factors relating to recommendations. Chapters or sections of the Report to be written. Possible outline of contents for the Report.

TUESDAY

0830 - Agenda Item 6. Structure of the Report. (straw man for discussion and re-hashing).
Executive Summary. 1 page, to be written last.

- INTRODUCTION, reasons for setting up the Workshop, Objectives, Sources of data, High priority themes considered in the Report. Limits and topics excluded, Determinants of scale and types of measurement at each spatial scale 1km to 3000km.
- Interfaces: Coastal zone, along coast, landward, seaward, atmospheric.
- Integrating technologies and methods: Remote Sensing, synoptic measurements, numerical modelling, nested models.
- Classification of environments, global categories.
- User groups and products: monitoring, hindcast, forecast. Benefits and timescales
- Priority of variables to measured, which can be measured now on a routine basis.
- Priority of variables to be measured, for which technology is at present inadequate.
- Measurements needed by the Coastal Module which are probably required also by other GOOS Modules.
- Measurements unique to the coastal zone. Geographical variability.
- TEMA, Capacity building.
- Priority of actions.
- Recommended procedures proposed to J-GOOS.
- ANNEXES.

1030-1045: Coffee Break.

1045- 1230 - Agenda Item 7. **Theme 1. Why do we need a coastal module of GOOS?**
Overall objectives, customer communities, end users, products, who requires what. Relation between research, the knowledge base, and what can be achieved in operational mode. Priorities, economics, justification, hazards, safety, efficiency, management, conservation, biodiversity, climate change. Useful timescales for development.
Conclusion with volunteers to assist in drafting.

1230-1330: LUNCH

1330-1730 - Agenda Item 8. **Theme 2. Geographical scales, spatial scales, time-scales, and interfaces.**
Concepts of scale from global to sub-1km. What is significant for the coastal module at each scale? Can any scales be ignored? Can we assume that at some scales other GOOS Modules, or other programmes, are observing all the necessary variables and making the data available? What variables, fields, or fluxes, does the coastal module require (if any) at the larger geographical scales? What variables are regional or site-specific?
Time-scales: What products do users require in the coastal zone with different time horizons? Hindcast, nowcast, forecast, monitoring? What time horizon can be achieved by

observing only in the coastal seas, on-land, or further offshore? What is the trade-off between time and spatial scale?

Interfaces: Given the conclusions on scales, what interfaces are needed with the hinterland and the open ocean to ensure that the coastal module produces results which are valuable to users?

Conclusion with volunteers to assist in drafting.

WEDNESDAY

AM. - Agenda Item 9. **Theme 3. How do we generate the products that people need?**

Observing system (general principles only), Data transmission, Quality Control, Data assembly, Data assimilation, Modelling, Product design, Output delivery systems, Market research, Communications and feedback from users, consultation.

Geographical variability: What are the priorities in different environments, stages of economic development? What is practical and achievable?

Conclusion with volunteers to assist in drafting.

PM - Agenda Item 10. **Theme 4. Definition of variables and products** which are probably most needed in each region (and achievable) , for different stages of economic development. What capacity building is needed?

Is it possible at this stage, on the basis of the experience of participants, to define groups of variables, leading to useful information products, which are practical as routine products in different regions? How near are we to doing this as a start? The ideal list will get longer and longer the further we look into the future, but what is reasonable now?

To what extent does any routine observing system with a limited number of variables have to be backed up by an extra range of local observations, perhaps in scientific research mode, which are essential to make reasonable decisions? Can we be holistic locally while gathering data in a more classical and limited mode on the large scale? How useful can a system be when it is manifestly a long way from perfect?

Conclusion with volunteers to assist in drafting.

THURSDAY

0830-1030 Agenda Item 11. **Theme 5 Technology**:

Review of available systems from satellite remote sensing, aircraft, HF radar, meteorological instruments, river gauging, precipitation, land-based observations in the hinterland, in water *in situ* instruments, water column measurements, profiling, buoy sensors, data telemetry, automatic quality control, calibration, data compression.

Which technology is mature and readily Seabee as standard? What is deficient? Where would the next tranche of investment produce the greatest benefit? What is the scope for cost reduction if standard instruments can be mass-produced?

What is the present validity of automatic data quality control prior to rapid data assimilation as per met data or GTSPP?

What are the technological weak links? Is there a technological obstacle in chemical or biological measurement or data processing which undermines the whole premise of the coastal module?

Are there new technologies which we should refer to, with some guess at timescales for introduction and/or relative cost?
Conclusion with volunteers to assist in drafting.

1100-1230 - Agenda Item 12. **Theme 6. Priorities for action and recommendations to J-GOOS**
There are two requirements here, firstly, those actions which we think are most important in the design and implementation of the coastal module, and our recommendations to J-GOOS as to how this might be put into practice.
Conclusion with volunteers to assist in drafting.

1230-1330 LUNCH

1330-1730 - Agenda Item 13 - Drafting, revision, discussion.

FRIDAY
AM - Agenda Item 13 continued - *ad hoc* programme of revision, drafting, and working on sections of the report.

PM, 1330-1530 - Agenda Item 14 - Review of the final text, and agreement on any outstanding
actions or sections which need one more revision. Conclusion of the workshop.

ANNEX III - Workshop Document List

The Global Ocean Observing System: Users, Benefits, and Priorities. National Academy Press. Washington, D.C. 1997.

Reference Documents - GOOS Bibliography.

Coastal Zones: A survey of data requirements for the operational community. June 22, 1995. European Space Agency.

The Strategy for EuroGOOS. A Summary. Ed. J.D. Woods, H. Dahlin, L. Droppert, M. Glass, S. Vallerga and N.C. Flemming.

IACMST GOOS Applications Workshops: Report. June 20, 1994.

IACMST Workshop on Economic Aspects of UK Participation in the Global Ocean Observing System (GOOS). Revised March 20, 1995.

IACMST Survey of UK Requirements for GOOS Data and Products. N.C. Flemming. December 1993.

2nd International Conference on Oceanography. Towards Sustainable Use of Oceans and Coastal Zones. Lisbon, November 14-19, 1994. The Economic Case for a Global Ocean Observing System. N.C. Flemming.

The U.S. Coastal Module of the Global Ocean Observing System (GOOS). Workshop report on The Sustainable Healthy Coasts Component. December 10-12, 1996. Bethesda, Maryland.

Development of North-East Asia Regional Global Ocean Observing System (NEAR-GOOS). Dong-Young Lee and Keisuke Taira. An Abstract.

Workshop on Coastal GOOS. Monitoring of Marine Environment in Coastal Waters of India. A presentation and paper by B.R. Subramanian.

Coastal Monitoring Network. Remotely Controlled German System Alerts Operators to METOC Events; Provides Monitoring & Analysis Data - New Technologies. By Prof. Dr. Hans-Diethard Knauth, Dr. Friedhelm Schroeder, Dieter Kohnke and Fritz Holzkamm.

Intergovernmental Oceanographic Commission (IOC). Reports of Meetings of Experts and Equivalent Bodies. Joint Scientific and Technical Committee for Global Ocean Observing System (J-GOOS). Third Session. Paris, France. April 23-25 1996.

IOC/WESTPAC /Co-ordinating Committee for the North-East Asian Regional - Global Ocean Observing System (NEAR-GOOS). First Meeting. Bangkok, Thailand. September 4-6 1996. UNESCO.

IOC, 1966. A Strategic Plan for the Assessment and Prediction of the Health of the Ocean: A Module of the Global Ocean Observing System. Prepared by the Health of the Ocean Panel of the Joint Scientific and Technical Committee for the Global Ocean Observing System. May 1996.

An Early Warning System for the Health of the Oceans. By Neil R. Andersen (ed.) Oceanography, Vol. 10, No. 1. 1997.

Coastal Agenda of GOOS: An Approach. (Draft)

First Report of the JGOFS/LOICZ Continental Margins Task Team. Edited by J. Hall and S.V. Smith. LOICZ Reports & Studies No. 7. JGOFS Report No. 21. 1996.

Report on the International Workshop on Continental Shelf Fluxes of Carbon, Nitrogen and Phosphorus. Edited by J. Hall, S.V Smith and P.R. Boudreau. LOICZ Reports & Studies No. 9. JGOFS Report No. 22.

The design and Planning of GOOS: The Role of the Coastal Module. A discussion paper prepared for the workshop by Peter Ryder.

Coastal Zone Studies in Paranagua Bay, Brazil. An abstract of the material presented at the workshop. E. Marone and R. Camargo.

ANNEX IV - Examples of Ongoing Coastal Monitoring Activities

The Workshop recognized that there are a number of coastal monitoring activities which have amassed valuable experience which could benefit GOOS. It considered some examples. Coral reef and mangrove ecosystems, for example, are being substantially impacted by human activities. Although their distribution is mainly tropical, they require global assessments.

Coral Reefs and the Global Coral Reef Monitoring Network

Loss of corals - Coral reefs are a powerful symbol of the ecological and economic significance of marine biodiversity. They have commanded huge research resources, indicated by the international coral reef congresses (last in Panama, June 96), and their own international journal of 16 years standing. The Great Barrier Reef is now subject to a long term and comprehensive monitoring system to define its ecological character and identify change, this has defined and tested effective reef monitoring practice. Despite all this, the worlds reefs are in serious decline, 10% are badly degraded and a higher proportion threatened. This has led to the foundation of the International Coral Reef Initiative from December 1994, a partnership of concerned nations and organizations to work for the good of coral reefs and related ecosystems (i.e. mangroves and seagrass beds), towards implementation of Chapter 17 of Agenda 21. Mangroves do not share this popularity, though are significant in diversity, productivity and usefulness, and equally damaged or threatened.

Threats to coral reefs were emphasized at the UN Global Conference on Sustainable Development of Small Islands Developing States (Barbados, 1994) during the launch the International Coral Reef Initiative (ICRI). ICRI held a major international meeting in Dumaguete City, Philippines (June, 1995) which called for the establishment of the Global Coral Reef Monitoring Network.

Corals and climate change - The concept of global coral reef monitoring has been discussed for many years. This culminated in December, 1991, when a group of experts discussed reef and mangrove monitoring, in response to growing global evidence of coastal ecosystem damage (UNEP- IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change, Pilot Projects on Mangroves and Coral Reefs, Monaco, 9/13-DEC-91). This led to the establishment of UNEP-IOC-IUCN-SPEI Global Task Team on the Implications of Climate Change on Coral Reefs in 1992, which reported that the imminent threats to coral reefs were anthropogenic, with climate change as a long-term threat to reefs, but a short-term threat to coral island communities (Wilkinson and Buddemeier, 1994)

For coral reefs, a sea level rise of 0.2 to 1.4 m by 2050 has been thought to be initially beneficial for the Australian Great Barrier Reef (Buddemeier and Hopley, 1988; Hopley and Kinsey, 1988). Improved tidal flushing will bring nutrients to wide reef flats with the effect of revitalizing coral growth, while improved sand transport will replenish sand cays. But sustained sea level rise in excess of 8 cm/ 100 years will drown reefs and erode coral cays, as shown from past periods of rapid sea level rise (Grigg and Epp, 1989). In the Caribbean, reef growth rates of up to 12 or 15 mm/ year have been recorded, but with reefs presently under stress from other factors such as hurricane damage, eutrophication and algal grazers, their ability to keep pace with rising sea level is not certain (Hendry, 1988).

CARICOMP (Caribbean Coastal Marine Productivity): A Network of Caribbean Marine Laboratories, Parks, and Reserves

The Caribbean Coastal Marine Productivity (CARICOMP) network of 25 marine laboratories, parks and reserves in 16 countries grew out of the 35 year old Association of Marine Laboratories of the Caribbean (AMLC) in 1990. CARICOMP is directed by a Steering Committee supported initially by the UNESCO COMAR (Coastal Marine) program and now by the Coastal Areas and Small Islands (CSI) program. Other support includes grants from the John D. and Catherine T. MacArthur Foundation for Phase I (1991-1994) and by the MacArthur Foundation and the Coral Reef Initiative of the U.S. Department of State for Phase II (1995-1999). The U.S. National Science Foundation, Division of International Programs and Division of Ocean Sciences, has provided funding for workshops and automated monitoring equipment respectively. The directors and administrators of each sponsoring institution and the national agencies from each CARICOMP country have provided financial and logistical support without which the field work could not be accomplished (CARICOMP, in press a).

Each site conducts a standardized, synoptic set of measurements of the structure, productivity, and associated physical parameters of relatively undisturbed coral reefs, sea grasses, and mangroves. The data are processed and reported quarterly and regional communications are facilitated by a Data Management Center at the University of the West Indies in Jamaica (CARICOMP in press b, c, d, e, f). The network provides a rapid response capability for regional phenomena such as coral bleaching, mass mortalities and diseases, and periodic oceanographic phenomena (CARICOMP in press g, Nagelkerken et al. in press). It also serves as an infrastructure for ground truth of satellite and remote sensing observations.

Participation in CARICOMP is open, requiring only a pledge (Memorandum of Understanding) that the protocols will be implemented and the data will be reported. The CARICOMP Methods Manual: Level I is deliberately simple and requires only basic equipment allowing universal participation (CARICOMP 1994). Future editions of the Manual (Level II, Level III, and so on) will permit the incorporation of more sophisticated observations, perhaps at a limited number of sites, into the network. There is an annual meeting which reinforces the sense of participation and affords the opportunity to air concerns, to discuss scientific and administrative issues, and to hold training workshops. Finally, while CARICOMP is based on natural science, the network is aware of the needs of social scientists for the scientific data appropriate to resources management.

To our knowledge the CARICOMP Network is the only presently functioning international coastal marine monitoring program based upon a regional network of academic and agency marine laboratories and facilities. The National Association of Marine Laboratories (NAML) in the U.S. and the Marine Research Stations Network (MARS) in Europe have conducted recent discussions of marine monitoring and research (Lasserre et al. 1994). The Caribbean Pollution (CARIPOL) program of UNEP and the Intergovernmental Oceanographic Commission (IOCARIBE) operated for 6 years from 1979 and was the first to collect regionally standardized data on oil pollution with centralized data analysis (Atwood et al. 1987). The ASEAN (Association of South East Asian Nations)-Australia Marine Science Project: Living Coastal Resources operated from 1984-1989 and developed a methods manual and a system of data reporting and analysis (English et al. 1994). A recent effort has been made to link tropical regions into a global network. The International Coral Reef Initiative (ICRI 1995) has proposed a Global Coral Reef Monitoring Network (GCRMN) as a part of the Global Ocean Observing System (GOOS) of the Intergovernmental Oceanographic Commission (IOC). The GCRMN will promote the development of a series of regional nodes and work towards globally standardized methods of assessing coral reefs.

The Regional Seas Program, established by UNEP after the landmark 1972 UN Conference on the Human Environment, clearly showed that regional marine ecosystems have scientific, social, and political dimensions. The political basis for cooperation in research and management of marine resources in the Caribbean was established by the UNEP Cartagena Convention on the conservation of marine resources and the control of pollution. This grew out of the UN Conference on the Law of the Sea (UNCLOS) to which numerous Caribbean countries are signatory. The success of the CARICOMP Network depends upon the recognition by the countries bordering the Caribbean of the inter-connection of sub-regions and the need for cooperation for regional resources management. The ultimate task of CARICOMP will be to participate in this development, to refine regional scientific observations and experiments, and to provide the appropriate data.

REFERENCES - see Annex 5 for References Cited

The Mangrove Ecosystem

Loss of mangroves - The world mangrove area is uncertain, due to insufficient evaluation of the resource, but is estimated between 15 and 30 million hectares (Lacerda et al., 1993).

The Indonesian archipelago has the greatest area of mangrove wetlands in the world (4.25 million ha), and is estimated to have lost 45 percent of its coverage (WRI 1992). An estimated 80,000 hectares of South Sulawesi's 110,000 hectares of mangrove wetlands have been lost, with extensive aquaculture ponds taking their place (Nurkin 1994).

Malaysia had 641,000 ha of mangroves remaining in 1992 (Clough, 1993), losing 6,000 ha each year between 1980 and 1990 (a total of 59, 500 ha, or 12% of its former area) to wood chipping and aquaculture. This trend has continued to the present day.

The total mangrove area in Thailand has decreased by more than 50% since 1960, when the mangrove area was estimated at 360,000 ha. The rate of loss was c. 4,000 ha/ year 1960-1975, 6,300 ha/ year 1975-1980 and 13,000 ha/ year 1980-1986 (Clough, 1993). This trend also continues.

Most Pacific island countries have records of substantial loss of mangrove area. Mangroves are a threatened habitat in the Northern Mariana Islands, and all significant mangrove areas in Tonga have either been cleared or clearance is scheduled (Ellison, in press).

Mangroves and climate change - Mangrove ecosystems are expected to show a sensitive response to predicted climate change and sea-level rise (Woodroffe, 1990; Ellison and Stoddart, 1991; Ellison, 1993; Pernetta, 1993; Woodroffe and Mulrennan, 1993; Ellison, 1994; Parkinson, DeLaune and White, 1994; Field, 1995; Snedaker, 1995; Woodroffe, 1995; Wolanski and Chappell, 1996). The nature of this response is complex, and subject to factors of environmental setting (Semeniuk, 1994; Bacon, 1994). Several expert groups have identified the need for a global monitoring system of mangrove response to climate change (IOC, 1990; IOC, 1991; UNEP/ UNESCO, 1993; UNEP, 1994), but none to date has been implemented.

This was the intention of the UNEP-IOC-WMO-IUCN Long-Term Global Monitoring System of Coastal and Near Shore Phenomena Related to Climate Change (IOC 1990, 1991), to be established as part of the Global Ocean Observing System. The South Pacific Regional Environment Program (SPREP) recently developed a Regional Wetland Action Plan, in which actions 3.3.1 and 3.3.5 are development of a regional monitoring system for mangrove ecosystem health (Idechong et al., 1995).

Details of Mangrove Monitoring: The variables to be measured and guidelines for site selection were investigated in detail by a meeting held during the formation of GOOS in 1991 (IOC, 1991).

The main priority is the determination the response of biological communities to potential climate change. This will involve measurement of some of the physical variables leading to these responses. Variables are listed as either of primary priority to the program, or of secondary importance; the primary variables represent the minimum set for measurement.

Measurement of biological variables (listed below) and certain physical variables will be made along a transect across the intertidal slope, as close to the center of the area as possible. Sampling frequency along this transect will be site dependent according to the scale and characteristics of the site.

Further to the systematic study specified below, resurvey should be made immediately following an extreme event (cyclones etc.)

Minimum data set - the following biological variables are the minimum necessary to assess for the impact of possible climate change on mangrove ecosystems. The interval between monitoring periods is envisaged as being 5 years during the operational life span of the system. During the pilot phase a shorter interval of 3 years is recommended to allow adequate data flow for calibration, testing, and establishment of necessary data management systems.

Because of the diversity of mangrove environments and in order to distinguish between the effects of climate and anthropogenic and other non-climatic impacts the observations of the following variables are the minimum required.

Variable	*Minimum Frequency*	*Methodology*
BIOLOGICAL		
Forest structure	5 years	ASEAN-Australia Manual or USM Manual
Tree size	5 years	ASEAN-Australia Manual or USM Manual
Density	5 years	ASEAN-Australia Manual or USM Manual
Tree growth	5 years	DBH increment (USM Manual)
Leaf area index	5 years	ASEAN-Australia Manual with modifications
Interstitial macro fauna	2 years	Holme & McIntyre, 1971; Hulings & Gray, 1971
PHYSICAL		
Relative sea level change	Continuous	GLOSS or tide gauge, part of met. station
Topography	5 years	EDM survey, relative to datum
Stratigraphy	Baseline	Coring and radiometric dating
Sedimentation rate	5 years	Inserted stakes, remain *in situ*
Meteorological data	Continuous	Automated meteorological station to WMO standards
Total radiation		
Air temperature		
Rainfall		
Wind speed and direction		
Relative humidity		
Atmospheric pressure		
Evaporation	Evaporimeter	WMO standards

Desirable additional variables (Stage 2) - Further to these minimal requirements, it would be desirable where possible to monitor the following indicators, to allow assessment and interpretation of biological responses to global change. A more complete analysis including the following variables could assist in interpretation of biological responses.

Variable	*Minimum Frequency*	*Methodology*
BIOLOGICAL		
Analysis of leaf pigments and tannins	5 years	Tannin analysis of treetop leaves
Height of pneumatophores	5 years	Ruler with EDM survey
PHYSICAL		
Sediment particle size	5 years	ASEAN-Australia manual
Redox potential	5 years	Inserted iron stakes, removed
Soil salinity	Seasonal	Squeeze cored sediment
Surface water temperature	Seasonal	Maximum/ minimum recorder

Additional optional variables (Stage 3) - Routine long-term measurements of these parameters may aid in the interpretation of the causes of observed change in mangrove communities.

Variable	***Minimum Frequency***	***Methodology***
BIOLOGICAL		
Plant ecophysiology	seasonal	Pearcy, et al., 1985.
Age distribution of macrofuana	5 year	ASEAN-Australia Manual
Predawn water potential	5 years	Scholander pressure bomb
PHYSICAL		
Wave conditions		Derive from meteorological data
Water circulation		GCNSMS Activity 2
Sediment ash free dry weight	5 years	Loss on ignition
Trace metals	5 years	To International standards
Pesticides	5 years	To International standards
Root flora	1 year	Qualitative observation
Carbon partitioning	5 years	to be determined
Rate of turnover of biomass	5 years	to be determined
Litter breakdown	5 years	to be determined

Sedentary Filter Feeding Organisms - "Mussel Watch"

Some monitoring is appropriate to be structured linearly along the coasts to evaluate the environmental issues focused in the critical and sensitive land/ water interface. An example of such monitoring is the IOC/ UNEP International Mussel Watch Project. This project is measuring levels of accumulation of toxic chemicals along coasts around the world to assess the threat to coastal environments of exposures to anthropogenically mobilized toxins in coastal ecosystems.

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CARICOMP (in press b) Physiography and setting of CARICOMP sites, a pattern analysis. Proc 8th Int Coral Reef Symposium

CARICOMP (in press c) Meteorological and oceanographic characterization of coral reefs, seagrass and mangrove habitats in the wider Caribbean. Proc 8th Int Coral Reef Symposium

CARICOMP (in press d) Structure and productivity of mangrove forests in the greater Caribbean region. Proc 8th Int Coral Reef Symposium

CARICOMP (in press e) Variation and ecological parameters of Thalassia testudinum across the CARICOMP network. Proc 8th Int Coral Reef Symposium

CARICOMP (in press f) CARICOMP monitoring of Caribbean coral reefs. Proc 8th Int Coral Reef Symposium

CARICOMP (in press g) Studies on Caribbean coral bleaching 1995. Proc 8th Int Coral Reef Symposium

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ANNEX VI - Useful Sites on the World Wide Web

Workshop participants provided the following Home Page addresses where information relevant to Coastal GOOS may be found. This list is not exhaustive, but provides a starting point for readers wishing to search for more information.

Regional GOOS Activities:
EuroGOOS Home Page: http://www.soc.soton.ac.uk/OTHERS/EUROGOOS/
NEAR-GOOS: http://www.jodc.jhd.go.jp/NEAR-GOOS.html

National GOOS activities:
Australian GOOS - http://www.BoM.GOV.AU/inside/ipa/gcos-goos/
Brazil: Centro do Estudos do Mar, Univ Fed do Paraná: http://200.17.232.65/
Paraná, Brazil state government: http://www/pr/gov/br/
Brazilian Parks and Reserves: http://www.pr.gov.br/turismo/parques.html
Brazilian Environmental Information:
http://www.bdt.org.br/bdt/portuges/index/biodiversidade/binbr
Brazilian Ministry of Science and Technology: http ://www.mct.gov.br
Korean Ocean Research and Development Institute, Coastal and Ocean Information Service:
http://sari.kordi.re.kr/~dylee
Japan Oceanographic Data Center - data online service system: URL =
http://www.jodc.jhd.go.jp
The Netherlands NetCoast: http://www/minvenw.nl/projects/netcoast/
United States of America
US GOOS: http://www.usgoos.noaa.gov/goos.html
US Coastal GOOS: http://www.usgoos.noaa.gov/coastalmission.html
US Coastal GOOS Data Workshop: http://www.nodc.noaa.gov/coast/index.html
The final report of the U.S. Coastal GOOS Workshop (of December 1996) is at:
http://www.usgoos.noaa.gov/amaster.html

International:
GOOS Support Office: http://www.unesco.org/ioc/goos/iocgoos.htm
Ocean Observing Panel for Climate:
http://WWW.BoM.GOV.AU/bmrc/mrlr/nrs/oopc/oopc.htm
Global Climate Observing Sysetm: http://www.wmo.ch/web/gcos/gcoshome.html
Global Terrestrial Observing System: http://www.fao.org/GTOS/
Joint Global Ocean Flux Study Continental Margins Task Team:
http://keep.oc.ntu.edu.tw/cmtt (also with LOICZ)
Land-Ocean Interactions in the Coastal Zone program: http://www.nioz.nl/loicz/
Global Sea Level Observing System: http://www.unesco.org/ioc/goos/gloss.htm
Global Coral Reef Monitoring Network: http://coral.aoml.noaa.gov/gcrmn/gcrmn.html

Miscellaneous:
Mussel Watch: http://www-orca.nos.noaa.gov/projects/nsandt/nsandt.html
Center for the Study of Marine Policy (University of Delaware):
http://www.udel.edu/CMS/csmp/

ANNEX VII - Terms of Reference for the GOOS Coastal Module Co-ordinating/Oversight Panel

1. The Panel is initially appointed for two years, and shall report to each meeting of J-GOOS. Every session of J-GOOS should rigorously assess the progress of the Panel and review its membership.

2. The Membership of the Panel shall, in the first place, be based on informal suggestions from the J-GOOS Coastal Module Workshop held in February 1997, combined with recommendations from existing Members of J-GOOS, and enquiries by the Chairman of J-GOOS. The Membership shall represent an appropriate range of professional skills, experience of coastal monitoring and forecasting, and representatives of organizations and agencies who are users of operational marine data, or providers of operational marine environmental services.

3. The Chair of the Panel shall be appointed by, and report to, the Chair of J-GOOS.

4. Meetings, publications, and other activities incurring costs, shall be planned in consultation with J-GOOS, and the GOOS Sponsor Agencies.

5. The Panel can be re-appointed, and the Terms of Reference and Objectives may be reviewed and revised at any meeting of J-GOOS, but only for a period of one year on each occasion, or until the next meeting of J-GOOS, whichever is the longer.

Objectives of the J-GOOS Coastal Module Co-ordinating/Oversight Panel

1. To review progress, co-ordinate, and report upon those activities of GOOS component bodies, the GOOS Support Office, and participating Member States and Agencies, which are related to production and delivery of marine environmental data products and services in the Coastal Zone.

2. To promote and encourage GOOS activities in the Coastal Zone.

3. Provide Guidance and advice to J-GOOS on matters concerning the Coastal Zone.

4. To communicate with other GOOS Module Panels, to ensure that the activities of the GOOS Coastal Panel are carried out in such a way as to maximize the effectiveness of GOOS as a whole, taking into account the requirements specified by other Panels or components of GOOS.

5. To communicate with other agencies, committees, and programmes, on behalf of J-GOOS, where there are necessary adjacent boundaries, requirements for exchange of data, or adoption of common procedures or policies.

6. To provide exchange of information among the national and regional GOOS planning efforts in the coastal zone so that a globally consistent template for the coastal module will emerge.

ANNEX VIII - Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
CARICOMP	Caribbean Coastal Marine Productivity Network
CTD	Conductivity, Temperature, Density Instrument
Euro-GOOS	European Regional GOOS
FAO	Food and Agriculture Organization of the UN
GCOS	Global Climate Observing System
GCRMN	Global Coral Reef Monitoring Network
GIS	Geographical Information System
GLOSS	Global Sea-Level Observing System
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observing System
HHWM	High-High Water Mark
HOTO	Health of the Oceans Module of GOOS
ICRI	International Coral Reef Initiative
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme (of ICSU)
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IUCN	The World Conservation Union
J-GOOS	Joint Scientific and Technical Committee for the Global Ocean Observing System (of IOC, ICSU, WMO)
JGOFS	Joint Global Ocean Flux Study (SCOR/IGBP)
LME	Large Marine Ecosystems
LMR	Living Marine Resources Module of GOOS
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP Core Project)
NEAR-GOOS	Northeast Asian Regional GOOS
OECD	Organization for Economic Cooperation and Development
PNG	Papua New Guinea
QA/QC	Quality Assurance / Quality Control
ROVs	Remotely Operated Vehicles
SCOR	Scientific Committee on Oceanic Research (of ICSU)
SPREP	South Pacific Region Environment Program
UNCED	United Nations Conference on Environment and Development

UNESCO		United Nations Educational, Scientific and Cultural Organization
VHF	Very High Frequency	
VTS	Vessel Traffic Service	
WMO		World Meteorological Organization
XBT	Expendable Bathythermograph	
XCTD		Expendable CTD

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