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The Global Ocean Observing System

GOOS

Prospectus 1998

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COOS STEERING COMMITTEE PREFACE TO COOS 1998

Background

The “GOOS 1998” Prospectus originated from discussion at the Third Session of the Joint Scientific and Technical Committee for the Global Ocean Observing System in April 1996 (J-GOOS Ill, Decision, para. 8.1). J-GOOS III concluded that, in view of the many documents and material that existed in the name of GOOS, originating from both within and without, it was timely to draft a document that consolidated this information, and pointed the way ahead.

A Planning Committee was convened intersessionally to oversee the drafting of the document, and a consultant engaged to undertake the gathering and consolidation of information and draft the document. An initial outline was reviewed at J-GOOS IV. J-GOOS IV formally endorsed the activity and agreed on a timetable for completion of the report, targeting the Year of the Ocean and the GOOS Agreements Meeting. In summary:

- J-GOOS constituted the Planning Committee.
- Enforce consistency with Principles and Strategy document.
- Publish GOOS 98 as a J-GOOS document.
- Implicitly recognised the document is going beyond consolidation and information by raising issues which have not been resolved by J-GOOS. J-GOOS (GSC) should address these intersessionally
- J-GOOS IV, April 1997, recognised that GOOS 1998 would need to be published as a document of the new GOOS Steering Committee (GSC).
- Resolution 3 by I-GOOS III (June 1997) states that GOOS 1998 be reviewed by the GSC for publication in summer 1998.

Statement from GSC

The GSC agreed the document is a valuable contribution to the GOOS background literature. The document represents a consolidation of existing material and has a content suited to the task of informing, and detailing the prospects of GOOS for governments, agencies, commercial companies, etc. To do this, it is important that the document takes a form which is accessible and truly informative, rather than representing a reference for scientific and technical detail. The document covers both existing systems and planned and developing systems, and the links to other organisations, for the purposes of providing information and alerting potential participants and users to the potential and relevance of GOOS.

The GSC stresses that the document is a summary document, rather than a definitive prescription for GOOS. It is a document which, for GOOS itself, consolidates the information contained in the many existing documents, and for the external community, provides an accessible and reliable account of the prospects for GOOS and the framework which is being developed to implement GOOS. The document contributes to the task of convincing governments and agencies to participate in the implementation of GOOS.

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The Prospectus for the Global Ocean Observing System (GOOS) 1998 shows that investment in GOOS by national and international operational agencies, by research organisations, commercial companies and by aid agencies, will produce economic and social benefits which are valuable on a global scale, and at a cost and risk which are acceptable.

The benefits accrue at the levels of individual companies and entities; at the levels of countries and government agencies; and internationally or globally in the form of better understanding and management of the marine environment, forecasting the global climate system, exploitation of marine resources, and improved management of safety at sea and mitigation of disasters such as coastal floods.

Predictions and information products will include the physical factors such as storms, currents, ice and waves, as well as living resources, health of the oceanic ecosystem, coastal erosion and flooding. Implementation of the GOOS relies upon exploiting the existing level of scientific knowledge as rapidly as possible, while pursuing in parallel further research which will be needed for GOOS to reach its maximum efficiency and usefulness.

A significant part of world economic activity and a wide range of services, amenities and social benefits depend upon efficient management of the sea. The GOOS was created in 1991 in response to the desire of many nations to improve forecasts of climate change, management of marine resources, to mitigate natural hazards, and improve utilisation and environmental protection in the coastal zone. For many countries marine resources and services provide 3-5% of their Gross National Product. For a few it is much higher. Some countries depend almost entirely upon marine fisheries and aquaculture for food protein.

Direct beneficiaries of the services produced by GOOS are the managers of coastal defences, ports and harbours, coastal civil engineering, fishing and fish farming, shellfish farming, shipping and ship routeing, the offshore oil and gas industry, cable- and pipe-laying, recreation and tourism. Indirect beneficiaries, through improved forecasting of seasonal and multi-year climate variability based on ocean observations, include agriculture and food production, and the management of energy, fresh water, and public health (e.g. for epidemics of malaria such as those associated with El Ninõ events).

The GOOS Prospectus 1998 shows that GOOS is achievable on a reasonable timescale, will start to produce useful products very quickly, that the products will continue to improve in scope, geographical coverage, and value, and that this can be achieved by logical and progressive development from the present state of science and operational services. Economic analysis suggests that the costs and benefits of the GOOS are likely to be similar to those of the World Weather Watch, the successful system that underpins all weather forecasting. The overall Principles upon which the GOOS is designed, and the Strategic Plan for achieving its long term goals have been published elsewhere, and are summarised in the Prospectus. This Prospectus is based on the Principles and the Strategic Plan.

The planning of GOOS is well-founded, and many countries have set up inter-departmental or inter-agency national GOOS Committees. There is a collaborative supervisory system linking the sponsor agencies at the UN level (IOC of UNESCO, WMO, and UNEP) and ICSU.

The legal basis for proceeding is defined by various international Conventions and Action Plans, including: the Convention on the Law of the Sea; the Framework Convention on Climate Change; the Biodiversity Convention; Agenda 21 (agreed at the United Nations Conference on Environment and Development in Rio in 1992); the Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities; the London Dumping Convention; the Agreement on Highly Migratory and Straddling Stocks; and others summarised in this Prospectus. The information provided by the GOOS will be needed by governments to meet their obligations under these Conventions.

The GOOS is part of an Integrated Global Observing Strategy (IGOS) in which the UN Agencies (UNESCO and its IOC, UNEP, WMO, and FAO) are working together and with ICSU and the satellite agencies (through the Committee on Earth Observing Systems). The GOOS forms the ocean component of the Global Climate Observing System (GCOS), and the marine coastal component of the Global Terrestrial Observing System (GTOS).

The Primary objectives of GOOS, simplified from the statement in Section 1.3 of the Prospectus are:

1. to specify the marine observational data needed to meet the needs of the world community of users of the oceanic environment;
2. to develop and implement an international co-ordinated strategy for the gathering, acquisition, and exchange of these data;
3. to facilitate the development of products and services based on the data, and widen their application in the use and protection of the marine environment;
4. to facilitate the means by which less-developed nations can increase their capacity to acquire and use marine data according to the GOOS framework;
5. to co-ordinate the ongoing operations of the GOOS and ensure its integration within wider global observational and environmental management strategies.

The GOOS is based on the past investment in marine scientific research, marine technological systems including earth observing satellites, and the existing operational observing and forecasting services.

EXECUTIVE SUMMARY

Scientific investment at the national, regional, and global level has been essential to make GOOS possible. In particular, global co-operative experiments such as the Tropical Ocean Global Atmosphere (TOGA) experiment, the World Ocean Circulation Experiment (WOCE), and the ongoing Global Ocean Ecosystem Dynamics (GLOBEC) and Climate Variability and Predictability (CLIVAR) provide the basis of global data sets, and rapid processing of global data which are essential. These and other large scale scientific projects will be required to improve the performance of GOOS, and to extend the range of its predictive ability, particularly in the field of chemical and biological factors.

The technological basis of GOOS consists of a variety of proven and novel *in situ* instruments and communication systems, a large number of coastal and shallow water observing stations, and a number of measuring techniques based on research ships or voluntary observing ships and ships of opportunity. Satellite observations of sea ice, sea surface temperature, ocean colour, variations in sea level and sea surface topography, wind, waves, and currents are essential for the success of the GOOS. It is important that these types of data should be available in future from standardised satellite missions which are planned at optimum cost for operational purposes. The ability of GOOS to convert observations rapidly into useful information depends critically upon the use of powerful computers and very sophisticated modelling software.

Many services already exist which provide local data and forecasts for marine operations such as entry to a large port, toxic algal blooms, oil slicks, the extent of sea ice, or the strength of currents near an oil rig. These services are provided by both governmental and commercial organisations. UN Agencies co-ordinate global collaboration in observations of sea level, upper ocean temperature, marine meteorology, and aspects of biology, fisheries, and pollution data. Some of these data are processed in real time to support forecasts. A supreme example of this has been the transition of the TOGA experiment into an operational observing system in the tropical Pacific to predict El Ninõ events. There is a great deal to be learnt from the experience of existing marine measuring and forecasting services, and GOOS will collaborate with them, and add the elements of complete global coverage, temporal continuity, and access to the most advanced global computer models.

The GOOS is being implemented through 5 overlapping phases:

1. planning, including design and technical definition;
2. operational demonstrations and pilot experiments;
3. incorporation of suitable existing observing and related activities and new activities that can be implemented now to constitute the GOOS Initial Observing System;
4. gradual operational implementation of the ‘permanent’ or ongoing Global Ocean Observing System;
5. continued assessment and improvement in individual aspects and in the entire system.

Phase 1. The first phase is well advanced. The initial shape of the GOOS is being developed by advisory panels dealing with: (i) climate; (ii) coastal seas; (iii) living marine resources; (iv) the health of the ocean (i.e. pollution); and (v) marine meteorological and oceanographic services. These panels report to the GOOS Steering Committee (GSC), that is responsible for the design and implementation of the GOOS. An Intergovernmental Committee (I-GOOS) assists in gaining intergovernmental support and approval for the design and implementation. Building the capacity of developing nations to contribute to and benefit from the GOOS is the responsibility of a Capacity Building Panel reporting to the GSC and I-GOOS.

During Phase 1 there have been studies of the economic, social, and scientific requirements of different countries and regions, and an assessment of these priorities against those observations which are already technically feasible, and those which require further research or technical development. These considerations lead to the initial observing system of GOOS, and an outline of the data management and data processing needs.

During the 1999 Assembly of IOC Member States will be invited to formally endorse the Principles of GOOS. National and regional operational agencies will have the opportunity to commit certain of their current operational resources to the GOOS to enhance its implementation. Such participation can be co-ordinated through national GOOS committees.

Phase 2 has begun with pilot projects to test the operation of the GOOS in specific regions, and to refine the GOOS subsystems. The NEAR-GOOS Pilot Project covers North East Asian seas. It focuses initially on developing data exchange between its partners, and on building the user community. In the future it will develop a numerical modelling and forecasting capability. The initial focus is primarily on physical data. In Europe, the EuroGOOS Association of 30 operational agencies from 16 countries is bringing researchers and operators together to create more efficient and effective observing systems for the Arctic, Baltic, Mediterranean, and North West Shelf of the continent, in the process identifying the needs for research and technology to make GOOS more effective. Ocean modelling and forecasting is high on their agenda, along with improved data exchange. An Atlantic-scale project is proposed to provide improved boundary conditions for the forcing of models for European coastal seas. While the initial focus of EuroGOOS is on physical parameters, chemical (nutrient) and biological (plankton) parameters also feature prominently in the EuroGOOS programme.

Active interest in building other regional projects has been expressed by the nations of: (i) the western Indian Ocean (WIOMAP); (ii) SE Asia (SEA-GOOS); (iii) Mediterranean (MED-GOOS); and (iv) south-west Pacific (Pacific-GOOS).

Technology demonstrator projects include PIRATA (Pilot Research Array (of buoys) in the Tropical Atlantic), and GODAE (Global Ocean Data Assimilation Experiment). PIRATA will demonstrate the value to climate forecasting of measurements from the equatorial Atlantic. GODAE will integrate and assimilate *in situ* and satellite data in real time into global ocean models in order to depict ocean circulation on time scales of a few days and space scales of a few tens of kilometres, to demonstrate the viability of the GOOS in this domain.

Phase 3 has begun with the creation of a GOOS Initial Observing System (GOOS-IOS), from a number of pre-existing observing systems, each of which will continue to serve the previous group of clients. The systems include: the upper ocean measurements of the Ship of Opportunity programme (SOOP); the meteorological observations of the Voluntary Observing Ship (VOS) network; data from the fixed and drifting buoys co-ordinated by the Data Buoy Co-operation Panel (DBCP); data from the buoys of the Tropical Atmosphere Ocean (TAO) array set up to monitor El Niño events in the equatorial Pacific; the tide gauge data from the Global Sea Level Observing System (GLOSS); data from the Global Temperature and Salinity Profile Programme (GTSPP); information from the Global Coral Reef Monitoring Network (GCRMN); communication through the Internet and the Global Telecommunications System (GTS) of the WMO; and the remotely-sensed metereological, ice, and ocean data from NOAA's operational satellites.

Apart from the GCRMN, these measuring systems are concerned primarily with physical observations. Consideration is now being given to what chemical and biological information is required and how to integrate it with physical data. Living marine resources exist mostly in the coastal zone, but the monitoring requirements for living resources and coastal seas ecosystems remain under development.

The challenge is to develop a systematic and integrated approach to coastal monitoring and forecasting based on the needs of coastal states and the goals of sustainable development. Examples of existing observing systems currently under consideration include the Harmful Algal Bloom (HAB) programme of the IOC; the international Mussel Watch programme, the Marine Pollution and Monitoring programme (MARPOLMON); and the Continuous Plankton Recorder (CPR) programme.

Phase 4 will involve continued integration of other components like these, and including new systems, with every attempt to enlarge the range of variables to include chemical and biological ones pertaining to the management of sustainable healthy coasts, including living marine resources and ecosystems. The maximum benefit from measuring and modelling the coastal zone will come from coupling the large time and space scales of ocean models to the nested models on the continental shelf. This will give a longer forecast horizon combined with the detailed local biological data based on new research.

It is likely that implementation will proceed following two parallel tracks:

1. coastal and shelf monitoring and prediction;
2. open ocean monitoring and prediction.

Within both themes it is suggested that investment should be focused on actions that:

1. have a high impact in terms of the delivery of the data and information that are needed;
2. are known to be feasible and thus likely to be successful;
3. continue and enhance activities that are already proving their worth, and encourage replication or expansion at a low level of risk;
4. comprise more substantial demonstration projects having community support;
5. give effect to intergovernmental conventions and agreements.

Within theme 1 (Coastal) the following actions, amongst others, are called for:

1. maintenance of the existing programmes of the GOOS-IOS;
2. development and application of automated biological and chemical sensors and methods needed to implement integrated observing systems, including physical-chemical-biological data, *in situ* and remote sensing, data telemetry, data assimilation and modelling;
3. development of observational programmes of sufficient duration, spatial extent, resolution and synopticity, to permit nowcasting, forecasting, and prediction;
4. expansion of geographic coverage of observing systems to include data sparse areas, and allow for comparative analysis of coastal systems;
5. building upon and expanding operational modelling services to include a wider range of marine modelling and forecasts;
6. creation of improved environmental data bases, including precision bathymetry, to underpin numerical modelling of shelf areas;
7. implementation of key priorities and achievement of key milestones in regional and national GOOS programmes;
8. transfer of experience where appropriate between regions, and between regional GOOS programmes.

Within theme 2 (Open Ocean) the following actions, amongst others, are called for:

1. the conduct of Observing System Simulation Experiments (OSSEs) to assist in prioritising the design of the GOOS for seasonal to inter-annual forecasting;
2. the prioritisation and implementation of *in situ* monitoring networks that complement the space component;
3. the definition of contributions needed to maintain and adapt existing systems;
4. establishment of GODAE as a unifying framework for a concerted effort involving both researchers and operational agencies;
5. incremental enhancement of the capabilities of observing systems by (i) addition of new or improved sensors (e.g. optical, acoustic, salinity) to existing platforms; (ii) operational support for PIRATA beyond 2000 AD; (iii) other extensions of the TAO network (e.g. to include the Indian ocean).
6. maintenance of important time series;

7. support for projects within WOCE, JGOFS, CLIVAR, and GLOBEC that contribute to the development of the GOOS;
8. support for regional monitoring and modelling of the Arctic, Atlantic and North Pacific;
9. Prioritisation of technology development in the fields of:

   acoustic thermometry and tomography;
   salinity measurements
   profiling floats
   autonomous underwater vehicles
   acoustic Doppler current profilers for deployment on VOS
   better definition of ice cover at the ice edge
   anti-fouling (for improved instrument performance)
   optics and acoustics for biological measurements

Coastal seas are strongly influenced by variability of the open ocean, including transports of heat, salt, and nutrients, and vertical upwelling. The living marine resources of coastal seas are affected by large-scale, open ocean phenomena. Examples include the El Niño and its massive impact on the fisheries of many countries, and the huge regime shifts in sardines and anchovies in many coastal fisheries in recent decades, which reflects some very large scale forcing. The Benguela Current Large Marine Ecosystem study is targeted on this issue.

In due course, when the module panels have developed their initial plans, the present modular panel structure of the GOOS will be changed to reflect the thematic structure of this implementation framework. Achievement of this implementation framework, and the necessary review of performance of the system required for Phase 5, demand the provision of appropriate structural support and expertise to: (i) conduct appropriate planning and co-ordination; (ii) ensure creation, maintenance and promotion of internationally accepted operational procedures and practices; (iii) facilitate training and awareness and capacity building.

Among the key items in the resulting infrastructure are:

1. establishment of an Information Centre;
2. development of networks for the real time and near real time telecommunications of data, assimilation into models, and dissemination of products and forecasts;
3. negotiation of a data policy according to the GOOS Principles (the default being application of the data policies of sponsoring organisations);
4. technology transfer and training for the purposes of capacity building, and sustained investment in capacity building.

In what follows, Chapter 1 defines the nature of the GOOS. Chapter 2 illustrates the strategic guidance for implementation. Chapter 3 sets out the legal, institutional, economic, scientific, technological, and operational basis for the GOOS. Chapter 4 explains the design of the GOOS, addressing the data and information management strategy being developed in the GOOS to generate and distribute data, products and services. Chapter 5 provides a framework for implementation as summarised above, based on the considerations and conclusions of the preceding chapters, suggests guidelines for establishing priorities, and recommends high priority actions for the immediate future. Finally, Chapter 6 uses examples to demonstrate how GOOS-like precursors have been or are being successfully applied in 6 prototype physical, chemical, and/or biological services or programmes.

RÉSUMÉ OFFICIEL

"Le Système mondial d'observation de l'océan (GOOS) en 1998 : un panorama" démontre que l'investissement effectué dans GOOS par les agences opérationnelles nationales et internationales, les organisations de recherche et les organismes d'assistance, apportera des avantages économiques et sociaux à l'échelle mondiale pour un coût et des risques acceptables.

Les bénéfices ne font que croître et embellir pour les sociétés et les individus, pour les pays et les agences gouvernementales, et à l'échelle internationale ou mondiale, grâce à une meilleure compréhension et une meilleure gestion du milieu marin, la prévision du système climatique mondial, l'exploitation des ressources marines, de même qu'à une meilleure gestion de la sécurité en mer et qu'à la minimisation des catastrophes comme les inondations des zones côtières.

Les prévisions et les informations comprendront des aspects physiques tels que les orages, les courants, les glaces et les vagues, mais aussi les ressources biologiques, la santé de l'écosystème océanique, l'érosion côtière et les inondations. La mise en œuvre du GOOS dépend de l'exploitation aussi rapide que possible des connaissances scientifiques actuelles, comme de la poursuite en parallèle d'autres recherches qui lui sont nécessaires pour atteindre une efficacité et une utilité maximales.

Une part importante de l'activité économique mondiale et d'un grand éventail de services, d'agréments et d'avantages sociaux dépend de l'efficacité de la gestion de la mer. Le GOOS fut créé en 1991 pour répondre à la demande de nombreux pays d'améliorer la prévision des changements climatiques et la gestion des ressources marines, de minimiser les dangers naturels et d'améliorer l'utilisation et la protection du milieu côtier. Pour de nombreux pays, les ressources et les services maritimes représentent 3 à 5% du produit national brut et, pour certains, bien davantage. Quelques pays dépendent presque entièrement de la pêche en mer et de l'aquaculture pour l'apport en protéines alimentaires.

Les bénéficiaires directs des services offerts par GOOS sont les responsables des défenses côtières, des ports et zones portuaires, de l'ingénierie civile côtière, de la pêche et de l'aquaculture (des poissons, crustacés et mollusques), de la navigation et des routes maritimes, de l'industrie offshore, de la pose des câbles et des canalisations, des zones de détente et du tourisme. Les bénéficiaires indirects, grâce à de meilleures prévisions de la variabilité climatique saisonnière et pluri-annuelle, fondées sur les données océaniques, comprennent la production agricole et alimentaire, la gestion de l'énergie et des eaux douces, ainsi que la santé publique (par exemple, pour les épidémies de malaria comme celles associées à El Niño).

Le panorama de 1998 démontre que le GOOS peut se réaliser dans des délais acceptables, qu'il commencera à fournir très rapidement des produits utiles, que ces produits s'amélioreront continuellement en termes de domaines d'application, de couverture géographique et de qualité, simplement en développant de manière logique et progressive l'état actuel de la science et des services opérationnels. L'analyse économique indique qu'il est possible que les coûts et profits du GOOS soient semblables à ceux de la Veille météorologique mondiale, le système qui étaye avec succès toutes les prévisions météorologiques.
Les principes qui ont servi à concevoir GOOS, ainsi que le plan stratégique destiné à atteindre ses buts à long terme, ont été publiés par ailleurs et sont résumés dans le panorama, qui y trouve ses fondements.

La planification du GOOS est bien établie et nombre de pays ont créé, entre leurs départements et agences, des Comités nationaux pour le GOOS. Un système de supervision rassemble les agences de parrainage, celles du système des Nations Unies (COI de l'UNESCO, OMM et PNUE) et le CIUS.

Le fondement légal est défini par diverses Conventions internationales et Plans d'action, dont: la Convention des Nations Unies sur le droit de la mer; la Convention-cadre des Nations Unies sur les changements climatiques; la Convention sur la diversité biologique; l'Action 21 (convenue lors de la Conférence des Nations Unies sur l'environnement et le développement, à Rio en 1992); le Plan d'action mondial pour la protection du milieu marin contre la pollution due aux activités terrestres; la Convention de Londres de 1972; l'Accord sur des stocks de poissons dont les déplacements s'effectuent tant à l'intérieur qu'au-delà de zones économiques exclusives (stocks chevauchants) et les stocks de poissons grands migrateurs; et d'autres énumérés dans cet Exposé. Les gouvernements devront utiliser les iinformations produites par le GOOS pour honorer leurs obligations découlant de ces Conventions.

Le GOOS fait partie d'une Stratégie mondiale intégrée d'observation (IGOS) dans laquelle les agences des Nations Unies (UNESCO et sa COI, PNUE, OMM et FAO), travaillent ensemble et avec le CIUS, ainsi qu'avec les agences spatiales (par l'intermédiaire du Comité sur les systèmes d'observation de la terre). Le GOOS constitue l'élément océanique du Système mondial d'observation du climat (GCOS) et la composante marine côtière du Système mondial d'observation de l'environnement terrestre (GTOS).

Les objectifs fondamentaux du GOOS, développés dans la section 1.3 du panorama, sont:

1. de spécifier les données d'observation marines nécessaires pour répondre aux besoins des utilisateurs du milieu océanique du monde entier;
2. d'élaborer et de mettre en œuvre une stratégie coordonnée internationalement pour rassembler, acquérir et échanger ces données;
3. de faciliter l'élaboration de produits et de services à partir de ces données, et d'élargir leur application en matière de protection et d'utilisation du milieu marin;
4. de faciliter la façon dont les pays les moins avancés peuvent accroître leur capacité d'acquérir et d'utiliser les données marines dans le contexte du GOOS;
5. de coordonner les activités en cours du GOOS et d'assurer son intégration au sein de stratégies plus larges d'observation et de gestion de l'environnement mondial.

Le GOOS se fonde sur les investissements passés dans la recherche scientifique marine, les technologies correspondantes (dont les satellites d'observation de la terre) et les services opérationnels d'observation et de prévision existants.

L'investissement scientifique aux niveaux national, régional et mondial a joué un rôle essentiel dans l'existence du GOOS. En particulier, les programmes nécessitant une coopération mondiale, comme l'expérience sur l'Océan tropical et l'atmosphère globale (TOGA), l'Expérience sur la circulation océanique mondiale (WOCE), les programmes en cours sur la Dynamique des écosystèmes océaniques à l'échelle mondiale (GLOBEC) et sur la Variabilité et prévisions climatiques (CLIVAR), sont à l'origine de jeux de données mondiaux et du traitement rapide de ces données, ce qui est essentiel. Ces programmes, ainsi que d'autres projets scientifiques de grande ampleur, serviront à améliorer les performances du GOOS et à élargir son éventail de compétences en matière de prévision, notamment dans les domaines de la chimie et de la biologie.

La base technologique du GOOS se compose d'un ensemble d'instruments de mesure in situ et de systèmes de communication, dont certains ont fait leurs preuves et d'autres sont nouveaux, d'un grand nombre de stations d'observation côtières et en eau peu profonde, d'un certain nombre de techniques de mesure à bord de navires océanographiques ou de navires d'observation bénévoles ou occasionnels. Les observations par satellite de la glace de mer, de la température de surface de la mer, de la couleur de l'océan, des variations du niveau de la mer et de la topographie de la surface de l'océan, du vent, des vagues et des courants marins sont essentielles au succès du GOOS. Il est important qu'à l'avenir ces types de données proviennent de missions satellitaires normalisées et planifiées à un coût optimum dans un but opérationnel. Le GOOS dépend fondamentalement de moyens informatiques puissants et de logiciels de modélisation complexes pour convertir rapidement les observations en informations utiles.

Bien des services existent déjà, qui proposent des données et des prévisions locales aux opérations maritimes, comme l'entrée dans un grand port, les efflorescences algales toxiques, les nappes de pétrole, l'étendue des glaces de mer, ou la force des courants près d'une plate-forme. Ces services sont offerts par des organisations gouvernementales et commerciales. Les agences des Nations Unies coordonnent la coopération mondiale pour les observations du niveau de la mer, de la température de l'eau superficielle, de la météorologie marine, ainsi que pour certaines données biologiques, halieutiques ou relatives à la pollution. Certaines de ces données sont traitées en temps réel pour alimenter les prévisions. Le passage de l'expérience TOGA à un système d'observation opérationnel dans le Pacifique tropical pour prévoir El Niño en est un exemple parfait. Nous avons beaucoup à apprendre de l'expérience des services de mesures et de prévisions existants; le GOOS collaborera avec eux, complètera la couverture mondiale, assurera la continuité temporelle et aura accès aux modèles numériques les plus modernes.

GOOS est mis en œuvre en 5 phases imbriquées:

1. la planification, comprenant la définition des concepts et des techniques;
2. des démonstrations opérationnelles et des expériences pilotes;
3. l'incorporation d'activités pertinentes d'observation et assimilées, ainsi que d'activités nouvelles qui peuvent être réalisées à présent, en un Système d'observation initial de GOOS;
4. graduellement, la mise en œuvre opérationnelle du Système “permanent” (ou “courant”) d'observation de l'océan;
5. l'évaluation et l'amélioration continues des parties comme du système dans son ensemble.

La première phase est bien avancée, et un “Plan stratégique et principes de GOOS” a été publié. Le contour initial de GOOS se dessine sous l'égide de groupes consultatifs pour : (i) le climat; (ii) les mers côtières; (iii) les ressources marines vivantes; (iv) la santé de l'océan (autrement dit, la pollution); et (v) les services de météorologie maritime et d'océanographie. Ces groupes rendent compte au Comité directeur de GOOS (GSC), qui est responsable de la conception et de la mise en œuvre de GOOS. Un comité intergouvernemental (I-GOOS) est chargé d'obtenir le soutien intergouvernemental et d'approuver la conception et la mise en œuvre. Constituer le potentiel requis par les pays en développement pour participer à GOOS et en bénéficier est placé sous la responsabilité d'un Groupe sur le renforcement des capacités, qui rend compte au GSC et à I-GOOS.

Pendant la première phase, des études ont été menées sur les besoins économiques, sociaux et scientifiques de différents pays et régions; ces priorités ont été confrontées aux observations qui sont déjà techniquement faisables et à celles qui nécessitent davantage de recherches ou de développement technique. Ces considérations mènent au système d'observation initial du GOOS, puis schématisent les besoins en gestion et traitement des données.

Lors de l'Assemblée de la COI, en 1999, les Etats membres seront invités à approuver officiellement les principes du GOOS. Les agences opérationnelles nationales et régionales auront la possibilité de s'engager, par certaines de leurs ressources opérationnelles existantes, à contribuer au GOOS et faire progresser sa mise en œuvre. Une telle participation peut être coordonnée par les comités nationaux du GOOS.

La phase 2 a commencé avec la constitution de projets pilotes destinés à tester comment GOOS peut fonctionner dans des régions données et à affiner ses sous-systèmes. Le projet pilote NEAR-GOOS recouvre les mers de l'Asie du nord-est. Il se concentre initialement sur l'échange de données entre ses partenaires et sur l'édification d'une communauté d'utilisateurs. Plus tard, il se dotera de modèles et de prévisions numériques. L'accent est mis en premier lieu sur les données physiques. En Europe, EuroGOOS, association de 30 agences opérationnelles de 16 pays, rassemble chercheurs et “opérationnels” pour créer des systèmes d'observation plus efficaces et compétents pour l'Arctique, la Baltique, la Méditerranée et le plateau continental nord-ouest du continent, dans le but d'identifier ce qu'il faut de recherches et de techniques pour rendre GOOS plus efficace. Modélisation et prévision figurent en très bonne place dans son plan de travail, avec l'amélioration de l'échange des données. Un projet à l'échelle de l'Atlantique se propose de fournir de meilleures conditions aux limites aux modèles des mers côtières européennes. Bien qu'initialement EuroGOOS se concentre sur les paramètres physiques, les paramètres chimiques (nutriments) et biologiques (plancton) apparaissent nettement dans le programme. Un vif intérèt pour de semblables projets se manifeste parmi les pays: (i) de l'océan Indien occidental (WIOMAP); (ii) du sud-est asiatique (SEA-GOOS); (iii) de la Méditerranée (MED-GOOS); et (iv) du Pacifique sud-ouest (Pacific-GOOS).

Les projets de démonstration technologique incluent PIRATA (Réseau expérimental de bouées ancrées dans l'Atlantique tropical) et GODAE (Expérience mondiale d'assimilation des données océaniques). PIRATA va démontrer la valeur des mesures dans l'Atlantique équatorial pour la prévision du climat. GODAE va intégrer et assimiler en temps réel des données in situ et satellitaires dans des modèles de l'océan mondial et décrire la circulation océanique à des échelles temporelle de quelques jours et spatiale de quelques dizaines de kilomètres, pour démontrer l'aptitude de GOOS dans ce domaine.

La phase 3 a démarré avec la création d'un Système d'observation initial de GOOS (GOOS-IOS), à partir de certains systèmes d'observation préexistants, qui continueront de servir les groupes d'usagers pour lesquels ils ont été établis. Ces systèmes comprennent : les mesures dans l'eau superficielle du Programme de navires occasionnels (SOOP); les observations météorologiques du réseau de navires d'observation bénévoles (VOS); les données des bouées mouillées et dérivantes que coordonne le Groupe de coopération pour les programmes de bouées de mesure (DBCP); les données du réseau de bouées Atmosphère tropicale - Océan (TAO), mis en place pour surveiller la venue d'El Niño dans le Pacifique équatorial; les données des marégraphes du Système mondial d'observation du niveau de la mer (GLOSS); les données du Projet sur les profils de température et de salinité à l'échelle du globe (GTSPP); les informations en provenance du Réseau mondial de surveillance des récifs coralliens (GCRMN); et les communications par le Système mondial de télécommunication (SMT) de l'OMM.

Si l'on excepte le GCRMN, ces systèmes de mesure portent principalement sur des observations physiques. On est à présent en train d'examiner quelles informations chimiques et biologiques sont requises et comment les intégrer aux données physiques. Les ressources marines vivantes se trouvent essentiellement dans la zone côtière, mais les besoins en termes de surveillance continue des ressources vivantes et des mers côtières restent encore à définir.

Le défi est de bâtir une approche intégrée, de haute qualité, de la surveillance et de la prévision côtières, qui prenne en compte les besoins des Etats côtiers et les objectifs d'un développement durable. Comme exemples de tels systèmes existants en cours d'examen, on peut citer: le Programme sur les efflorescences algales nuisibles (HAB) de la COI; le Programme international de surveillance des moules; le Programme de surveillance continue de la pollution marine (MARPOLMON); et le Programme d'enregistrement en continu du plancton (CPR).

La phase 4 comprendra l'intégration continue d'autres composantes similaires aux précédentes, dont des systèmes nouveaux, en faisant le maximum pour élargir la gamme des paramètres et en inclure qui soient chimiques ou biolologiques et relèvent d'une gestion des côtes qui les rendent durablement saines, avec leurs resources vivantes et leurs écosystèmes. Le plus grand bénéfice pour les mesures et la modélisation de la zone côtière proviendra de l'association des grandes échelles de temps et d'espace des modèles océaniques avec les modèles imbriqués sur le plateau continental. Cela offrira un horizon de prévisions plus lointain, associé à des données biologiques locales détaillées.

La mise en œuvre progressera suivant deux thèmes parallèles:

1. surveillance et prévision pour la côte et le plateau continental;
2. surveillance et prévision au large.

Dans ces deux thèmes, on investira dans des activités qui:

1. influent considérablement sur la disponibilité des données et des informations requises;
2. sont reconnues comme faisables et donc fortement susceptibles de réussir;
3. poursuivent et mettent en valeur des actions qui ont déjà fait leurs preuves, et encouragent leur reprise ou leur extension à peu de risques;
4. comprennent des projets de démonstration plus fondamentaux, sur une base commune;
5. donnent consistence aux conventions et accords intergouvernementaux.

Dans le cadre du premier thème (les côtes), les actions suivantes sont requises:

1. le maintien des programmes existants du GOOS-IOS;
2. l'élaboration et l'utilisation de capteurs biologiques et chimiques automatiques, comme des méthodes nécessaires à la réalisation de systèmes d'observation intégrés, comprenant des données physiques, chimiques et biologiques, des mesures in situ et par télédétection, la télémesure, l'assimilation des données et la modélisation;
3. l'élaboration de programmes d'observation d'une durée, d'une étendue, d'une résolution et d'une synopticité suffisantes pour permettre les prévisions immédiate et à plus long terme;
4. l'extension de la couverture géographique des systèmes d'observation pour inclure des zones pauvres en données et permettre l'analyse comparative des systèmes côtiers;
5. l'évolution et l'expansion des services opérationnels de modélisation pour inclure un large éventail de modélisations et de prévisions marines;
6. la création de meilleures bases de données environementales, dont une bathymétrie précise, pour étayer la modélisation numérique des zones du plateau;
7. la conformité aux priorités principales et la réalisation d'objectifs marquants au sein des programmes régionaux et nationaux du GOOS;
8. l'échange d'expériences, le cas échéant, entre les régions et les programmes régionaux du GOOS.

Dans le cadre du deuxième thème (au large), les actions suivantes sont requises:

1. la réalisation d'expériences de simulation des systèmes d'observation (OSSEs) pour aider à définir les priorités dans la conception du GOOS pour les prévisions allant de la saison à plusieurs années;
2. la réalisation, tenant compte des priorités, de réseaux de surveillance in situ en complément de la composante spatiale;
3. la définition des contributions nécessaires au maintien et à l'adaptation des systèmes existants;
4. la réalisation de l'expérience GODAE, en tant qu'ensemble unifié rassemblant chercheurs et "opérationnels" dans un même effort;
5. l'amélioration graduelle du potentiel des systèmes d'observation: (i) en ajoutant de nouveaux ou de meilleurs capteurs (par exemple: optique, acoustique, salinité) aux plates-formes existantes; (ii) en offrant un

soutien opérationnel à PIRATA après l'an 2000; (iii) en proposant d'autres extensions du réseau TAO (par exemple, pour inclure l'océan Indien);

6. le maintien des séries temporelles importantes;

7. le soutien des projets qui, dans le cadre de WOCE, JGOFS, CLIVAR et GLOBEC, contribuent au développement du GOOS;

8. le soutien de la surveillance et de la modélisation régionales dans l'Arctique, l'Atlantique et le Pacifique nord;

9. l'établissement de priorités pour le développement technologique dans les domaines suivants:

- la thermométrie et la tomographie acoustiques;
- les mesures de salinité;
- les profileurs autonomes;
- les véhicules sous-marins autonomes;
- les profileurs de courant par effet Doppler acoustique sur des navires d'observation bénévoles;
- une meilleure définition de la couverture des glaces;
- les procédés antisallissures (pour une meilleure performance des instruments);
- l'optique et l'acoustique appliquées aux mesures biologiques.

Les mers côtières sont fortement influencées par la variabilité des eaux du large, dont les transports de chaleur, de sel et de nutriments, ainsi que par les remontées d'eau froide. Les ressources biologiques des mers côtières sont influencées par les phénomènes à grande échelle des eaux du large. Parmi les exemples, on peut citer El Niño et les énormes variations dans les prises d'anchois et de sardines qu'on connues nombre de pêcheries dans les dernières décennies, ce qui reflète des contraintes à très grande échelle. L'étude du grand écosystème marin du courant de Benguela se concentre sur cette question.

En temps utile, lorsque les groupes chargés des modules auront élaboré leurs plans initiaux, la structure modulaire actuelle de GOOS devra se transformer pour refléter la structure thématique de son cadre de mise en œuvre. Réaliser ce qui précède et revoir le fonctionnement du système, ce qui est l'objet de la phase 5, demande un soutien structurel et de l'expertise pour: (i) mener à bien la planification et la coordination requises; (ii) créer, entretenir et promouvoir des procédures et des pratiques opérationnelles acceptées internationalement; (iii) faciliter la formation, l'information et la constitution du potentiel requis.

Les éléments clés de l'infrastructure qui s'en dégage comprendront:

1. l'établissement d'un centre d'information;

2. le développement de réseaux pour la télécommunication des données, leur assimilation dans les modèles et la dissémination des produits et des prévisions, en temps réel et quasi-réel;

3. la négociation d'une politique concernant les données qui soit conforme aux principes du GOOS (à défaut, on appliquera la politique des parrains);

4. le transfert technologique et la formation pour constituer le potentiel requis, ainsi qu'un investissement durable dans ce domaine.

Dans ce qui suit, le chapitre 1 définit la nature du GOOS. Le chapitre 2 illustre la stratégie de son exécution. Le chapitre 3 définit les formes juridique, institutionnelle, économique, scientifique, technologique et opérationnelle du GOOS. Le chapitre 4 explique la conception du GOOS, abordant la stratégie de gestion des données et de l'information qui y est développée pour générer et distribuer les données, les produits et les services. Le chapitre 5 donne un cadre de travail pour la réalisation de ce qui précède, fondé sur les considérations et conclusions des chapitres précédents, suggère des lignes directrices pour l'établissement de priorités et recommande des actions hautement prioritaires dans l'avenir immédiat. Enfin, le chapitre 6 utilise des exemples qui montrent comment les précurseurs du GOOS ont été, ou sont, impliqués avec succès dans 6 services ou programmes prototypes en physique, chimie ou biologie.

El Prospecto del Sistema Mundial de Observación de los Océanos (GOOS) 1998 muestra que la inversión en GOOS realizada por entidades operacionales nacionales e internacionales, por organizaciones de investigación y por agencias de asistencia, producirá beneficios económicos y sociales valiosos a escala global y a un coste y riesgo que sean aceptables.

Los beneficios se han producido a nivel de compañías y entidades individuales, a nivel de países y entidades gubernamentales, e internacional o globalmente en forma de un mejor entendimiento y control del medio marino, pronóstico del sistema mundial del clima, explotación de los recursos marinos y mejor control de seguridad en el mar y mitigación de desastres tales como flujos costeros.

Los pronósticos y los productos de información incluirán factores físicos como tormentas, corriente, hielo y olas, así como recursos vivos, salud del ecosistema oceánico, erosión e inundaciones costeras. La implementación del GOOS depende de la explotación del nivel existente de conocimientos científicos lo más rápidamente posible, al tiempo que se sigue más investigación necesaria para que GOOS alcance su máxima eficacia y utilidad.

Una parte muy importante de la actividad económica mundial y una amplia gama de servicios, amenidades y beneficios sociales dependen del control eficaz del mar. GOOS se creó en 1991 como respuesta al deseo de muchas naciones de mejorar los pronósticos de cambios de clima, control de los recursos marinos, reducir los peligros naturales y mejorar el uso y protección medioambiental de las zonas costeras. Para muchos países, los recursos marinos y los servicios proporcionan un 3-5% de su Producto Nacional Bruto. Para unos pocos es mucho más alto. Algunos países dependen casi en su totalidad de la pesca marina y acuacultura para proteínas alimentícias.

Los beneficiarios directos de los servicios producidos por GOOS son los directores de defensas costeras, puertos y bahías, ingenieros civiles costeros, pesca y acuacultura, navegación y rutas marinas, la industria petrolífera y del gas submarina, tendido de cables y tubería, recreación y turismo. Los beneficiarios indirectos, a través de mejores pronósticos de la variabilidad del clima de muchos años por sesiones basadas en las observaciones del océano, incluyen la agricultura y producción alimentícia y el control de energía, agua dulce y salud pública (p.ej. para epidemias de malaria así como las asociadas con los acontecimientos de El Niño).

El Prospecto GOOS 1998 muestra que GOOS puede conseguirse dentro de una escala de tiempo razonable, que empezará a producir productos útiles rápidamente, que los productos seguirán mejorando en envergadura, cobertura geográfica y valor, y que todo esto puede conseguirse mediante el desarrollo lógico y progresivo del estado actual de la ciencia y los servicios operacionales. El análisis económico sugiere que los costos y beneficios del GOOS van a ser parecidos a los de la Vigilancia Meteorológica Mundial, el logrado sistema que secunda la predicción meteorológica.

Los Principios globales sobre los que se designa GOOS y el Plan Estratégico para conseguir sus metas a largo plazo han sido publicadas en otros documentos y sólo se resumen en el Prospecto. Este Prospecto se basa en los Principios y en el Plan Estratégico.

La planificación del GOOS es bien conocida, y muchos países han establecido Comités GOOS nacionales interdepartamentales o interorganismos. Existe un sistema supervisor de colaboración que vincula los organismos patrocinadores a nivel NU (COI de UNESCO, OMM y PNUMA) y CIUC.

Varias Convenciones y Planes de Acción internacionales han definido las bases legales para medidas, incluyendo: la Convención de las Naciones Unidas sobre el Derecho del Mar, la Convención Marco de las Naciones Unidas sobre el Cambio Climático, la Convención sobre la Biodiversidad, Agenda 21 (acordada en la Conferencia de las Naciones Unidas sobre el Medio Ambiente y el Desarrollo celebrada en Río en 1992), el Programa de Acción Mundial para la Protección del Medio Marino Frente a las Actividades Realizadas en Tierra, el Convenio de Londres 1972, el Acuerdo sobre Stocks Altamente Migratorios y Traszonales, y otros resumidos en este Prospecto. La información facilitada por GOOS será necesaria para que los gobiernos puedan satisfacer sus obligaciones bajo estas Convenciones.

GOOS es parte de una Estrategia Integrada de Observación Mundial (IGOS) en la que los Organismos de las NU (UNESCO y su COI, PNUMA, OMM y FAO) trabajan conjuntamente y con CUIC y los organismos de satélite (a través del Comité sobre Sistemas de Observación de la Tierra). GOOS forma el componente oceánico del Sistema Mundial de Observación del Clima y el componente costero marino del Sistema Mundial de Observación Terrestre (GTOS).

Los objetivos primordiales del GOOS, simplificado de la declaración que aparece en el apartado 1.3 del Prospecto, son:

1. Especificar los datos observacionales marinos necesarios para satisfacer las necesidades de la comunidad mundial de usuarios del medio oceánico.
2. Desarrollar e implementar una estrategia coordinada internacional para la recopilación, adquisición e intercambio de estos datos.
3. Facilitar los productos y servicios de desarrollo basados en los datos y ampliar su aplicación en el uso y protección del medio marino.
4. Facilitar los medios por los que naciones menos desarrolladas pueden aumentar su capacidad para adquirir y usar datos marinos según el marco del GOOS.
5. Coordinar las operaciones en marcha del GOOS y asegurar su integración dentro de las estrategias más amplias de control observacional y medioambiental global.

GOOS se basa en la inversión efectuada en el pasado en investigación científica marina, sistemas tecnológicos marinos incluyendo los satélites de observación terrestre y los ya existentes servicios de observación operacional y pronóstico.

La inversión científica a nivel nacional, regional y global ha sido esencial para hacer del GOOS algo posible. En especial, los experimentos cooperativos globales como el experimento de los Océanos Tropicales y la Atmósfera Mundial (TOGA), el Experimento Mundial sobre la Circulación Oceánica (WOCE) y la Dinámica de los Ecosistemas Oceánicos Mundiales (GLOBEC) y la Variabilidad y Predictabilidad del Clima (CLIVAR) en marcha, facilitan la base de los conjuntos de datos globales y el rápido procesamiento de datos globales imprescindibles. Estos y otros proyectos científicos de gran escala serán necesarios para mejorar la actuación del GOOS y para ampliar la gama de su capacidad predictiva, especialmente en el campo de los factores químico y biológico.

La base tecnológica del GOOS consiste en diferentes instrumentos *in situ* probados y nuevos así como sistemas de comunicación, varias estaciones de observación de aguas costeras y rasas y varias técnicas de medición basadas en buques de investigación o buques de observación voluntaria y de oportunidad. Las observaciones por satélite del hielo de mar, temperatura de la superficie del mar, colores del océano, variaciones en el nivel del mar y en la topografía de superficie del mar, viento, olas y corrientes son esenciales para el éxito del GOOS. Es importante que estos tipos de datos estén disponibles en el futuro a partir de misiones normalizadas por satélite, las cuales han sido planificadas a un coste óptimo para objetivos operacionales. La capacidad del GOOS en convertir rápidamente las observaciones en infomación útil depende del uso de ordenadores grandes y programas de modelación muy sofisticados.

Ya existen muchos servicios, que proporcionan datos locales y predicen las operaciones marinas como la entrada a un puerto grande, floraciones de algas marinas tóxicas, manchas de hidrocarburo flotando en el agua, la extensión del hielo de mar, o la fuerza de las corrientes cerca de una plataforma de perforación petrolífera. Tanto las organizaciones gubernamentales como las comerciales ofrecen estos servicios. Los Organismos NU coordinan la colaboración global sobre observaciones del nivel del mar, temperatura de la capa superior de los océanos, meteorología marina y aspectos de biología, pesca y datos sobre polución. Algunos de estos datos se procesan en tiempo real para asistir a los pronósticos. Un ejemplo excelente de esto ha sido la transición del experimento TOGA a un sistema operacional de observación en el Pacífico tropical para predecir los eventos de El Niño. Hay mucho que aprender de la experiencia de las medidas marinas existentes y de los servicios de pronósticos, y GOOS colaborará con ellos y añadirá los elementos de una cobertura global completa, continuidad temporal y acceso a los modelos globales de ordenadores más avanzados.

GOOS se está implementando a través de 5 fases que se superponen:

1. Planificación, incluyendo el diseño y la definición técnica.
2. Demostraciones operacionales y experimentos piloto.
3. Incorporación de actividades relacionadas y de observación existentes que sean adecuadas, y nuevas actividades que pueden implementarse ahora para constituir el Sistema Inicial de Observación GOOS.
4. Implementación operacional paulatina del Sistema de Observación Oceánica Mundial.
5. Valoración y mejora continua de los aspectos individuales y de todo el sistema.

Fase 1. La primera fase está ya muy avanzada. Paneles asesores están desarrollando la forma inicial del GOOS. Estos paneles tratan con: (1) clima; (2) mares costeros; (3) recursos marinos vivos; (4) el estado del océano (es decir, contaminación); y (5) servicios meteorológicos y oceanográficos marinos. Estos paneles informan al Comité Directivo GOOS (GSC), que es el responsable del diseño e implementación del GOOS. Un Comité Intergubernamental (I-GOOS) ayuda en la obtención de asistencia intergubernamental y aprobación de los diseños y la implementación. Crear la posibilidad de que las naciones en vías de desarrollo contribuyan con GOOS y se beneficien del mismo, es responsabilidad del Panel de Creación de Capacidad que informa a GSC e I-GOOS.

Durante la Fase 1 se han efectuados estudios de requisitos económicos, sociales y científicos de diferentes países y regiones y una valoración de estas prioridades en comparación con aquellas que ya son técnicamente factibles y aquellas que requieren más investigación o desarrollo técnico. Estas consideraciones llevaron al sistema inicial de observación del GOOS y al perfil de las necesidades de gestión de datos y de procesamiento de datos.

Durante la Asamblea de 1999 de la COI, se invitará a los Estados Miembros a que ratifiquen los Principios del GOOS. Los organismos operacionales nacionales y regionales tendrán la oportunidad de someter algunos de sus recursos operacionales actuales a GOOS para realzar su implementación. Dicha participación puede coordinarse a través de comités GOOS nacionales.

La Fase 2 empezó con proyectos piloto para comprar la operación del GOOS en unas regiones específicas y refinar los subsistemas GOOS. El Proyecto Piloto NEAR-GOOS cubre los mares del Asia Nororiental. En un principio se centra en el desarrollo de intercambio de datos entre sus socios y en la creación de una comunidad de usuarios. En el futuro desarrollará un modelo numérico y posibilidades de predicción. El enfoque inicial se centra principalmente en los datos físicos. En Europa, la Asociación EuroGOOS de 30 organismos operacionales pertenecientes a 16 países reúne a investigadores y operadores para crear sistemas de observación más eficaces y efectivos para el Artico, Báltico, Mediterráneo y Plataforma Noroccidental del continente, dentro del proceso de identificar las necesidades de investigación y tecnología para hacer que GOOS sea más efectivo. La modelación oceánica y la predicción son unos de los primeros puntos de la agenda, junto con un mejor intercambio de datos. Se ha propuesto un proyecto a escala Atlántico para ofrecer mejores condiciones limítrofes para el reforzamiento de modelos para los mares costeros europeos. Aunque el enfoque inicial de EuroGOOS se centra en los parámetros físicos, los parámetros químicos (nutrientes) y biológicos (plancton) también tienen un lugar prominente en el programa EuroGOOS.

También se ha expresado interés por la creación de otros proyectos regionales. Los países que han expresado este interés son: (1) del Océano Indico occidental (WIOMAP); (2) hacia Asia del Sudeste (SEA-GOOS); (3) Mediterráneo (MED-GOOS); y Pacífico del Sudoeste (Pacific-GOOS).

Los proyectos de demostración de tecnología incluyen PIRATA (Serie de Investigación Piloto (de boyas) en el Atlántico Tropical), y GODAE (Experimento sobre Asimilación de Datos Oceánicos Mundiales). PIRATA demostrará el valor del pronóstico del clima sobre mediciones del Atlántico ecuatorial. GODAE integrará y asimilará datos in situ y por satélite en tiempo real en modelos oceánicos mundiales, a fin de representar la circulación oceánica en escala de tiempos de unos cuantos días y escalas de espacio de unas cuantas decenas de kilómetros, a fin de demostrar la viabilidad del GOOS en este terreno.

La Fase 3 empezó con la creación de un Sistema Inicial de Observación GOOS (GOOS-IOS), partiendo de varios sistemas de observación preexistentes, cada uno de los cuales siguirá sirviendo al grupo anterior de usuarios. Los sistemas incluyen: las mediciones de la capa superficial del Programa de Buques que Colaboran Ocasionalmente (SOOP), las observaciones meteorológicas de la red de Buques de Observación Voluntaria (VOS), datos de las boyas fijas y de deriva coordinados por el Panel de Cooperación sobre Boyas de Acopio de Datos (DBCP), datos de las boyas de la Red para la Observación Océano-Atmósfera en los Mares Tropicales (TAO) establecida para supervisar los acontecimientos de El Niño en el Pacífico ecuatorial; datos de los mareógrafos del Sistema Mundial de Observación del Nivel del Mar (GLOSS), datos del Proyecto Piloto Mundial sobre Temperatura y Salinidad (GTSPP), información de la Red Mundial de Vigilancia de Arrecifes Coralinos (GCRMN), y comunicación a través de Internet y del Sistema Mundial de Telecomunicaciones (GTS) de OMM.

Además de GCRMN, estos sistemas de medición se preocupan principalmente de las observaciones físicas. Ahora se está considerando qué información química y biológica se necesita y cómo integrarla con los datos físicos. Los recursos marinos vivos existen principalmente en la zona costera, pero los requisitos de supervisión para los recursos vivos y los ecosistemas costeros del mar siguen estando en desarrollo.

El reto consiste en desarrollar un enfoque sistemático e integral para el control costero y el pronóstico en base a las necesidades de estados costeros y metas sobre desarrollo sostenible. Ejemplos de sistemas de observación existentes que se consideran en la actualidad incluyen el Programa de Floraciones de Algas Nocivas (HAB) de COI, el Programa Internacional de Vigilancia de Mejillones, el Programa de Vigilancia de la Contaminación Marina (MARPOLMON) y el Programa de Registro Continuo de Plancton (CPR).

La Fase 4 implicará la integración continua de otros componentes como estos, y la inclusión de nuevos sistemas, con cualquier intento de engrandecer la gama de variables para incluir los químicos y biológicos que pertenezcan a la gestión sostenible de costas saludables, incluyendo los recursos y ecosistemas marinos vivos. El beneficio máximo de la medición y modelación de la zona costera procederá del acoplamiento de las escalas de tiempo y espacio de los modelos oceánicos a los modelos anidados en la plataforma continental. Esto ofrecerá un pronóstico más duradero junto con datos biológicos locales detallados.

La implementación continuará siguiendo dos rutas paralelas:

1. Supervisión y pronóstico costero y de la plataforma.
2. Supervisión y pronóstico del mar abierto.

Dentro de estos temas, se sugiere la inversión en acciones que:

1. Tengan un impacto importante en cuanto a entrega de datos e información necesarios se refiere.
2. Se sepa que son factibles y por ello vayan a tener un posible éxito.
3. Continuen y realcen actividades que ya hayan demostrado su validez y fomentando la reproducción o expansión de un nivel de bajo riesgo.
4. Consten de más proyectos sustanciales de demostración que tengan el apoyo de la comunidad.
5. Pongan en efecto las convenciones y acuerdos intergubernamentales.

Dentro del tema 1 (costero) se requieren las siguientes acciones:

1. Mantenimiento de los programas del GOOS-IOS existentes.
2. Desarrollo y aplicación de sensores y métodos biológicos químicos y biológicos automáticos necesarios para implementar los sistemas de observación integrados, incluyendo los datos físicos-químicos-biológicos, sensibilidad *in situ* y remota, telemetría de datos, asimilación de datos y modelación.
3. Desarrollo de los programas de observación con suficiente duración, extensión espacial, resolución y sinopticidad, para permitir predicción del momento, predicción del futuro y pronóstico.
4. Expansión de la cobertura geográfica de los sistemas para incluir zonas dispersas de datos y permitir el análisis comparativo de sistemas costeros.
5. Creación y expansión de los servicios de modelación operacional a fin de incluir una gama más amplia de modelación y pronósticos marinos.

6. Creación de mejores bases de datos ambientales, incluyendo batimetría para secundar la modelación numérica de las zonas de plataforma.
7. Implementación de las prioridades clave y logro de las metas clave en los programas GOOS regionales y nacionales.
8. Transferencia de experiencia donde proceda entre regiones y entre programas GOOS regionales.

Dentro del tema 2 (Mar Abierto) se requiren las siguientes acciones:

1. La conducta de los Experimentos de Simulación del Sistema de Observación (OSSEs) para ayudar a la priorización del diseño del GOOS para pronóstico de estacional y/o interanual.
2. La priorización e implementación de redes de supervisión *in situ* que complemente el componente espacial.
3. La definición de contribuciones necesarias para mantener y adaptar los sistemas existentes.
4. Establecimiento de GODAE como un marco unificador para los esfuerzos que impliquen investigadores y organismos operacionales.
5. Realce incremental de las posibilidades de sistemas de observación mediante (1) la añadidura de nuevos o mejores sensores (p.ej. óptico, acústico, de salinidad) a las plataformas existentes; (2) asistencia operacional para PIRATA después del año 2000, (3) otras extensiones de la red TAO (p.ej. incluyendo el Océano Indico).
6. Mantenimiento de series de tiempos importantes.
7. Asistencia para proyectos dentro de WOCE, JGOFS, CLIVAR y GLOBEC que contribuyan al desarrollo del GOOS.
8. Asistencia para la supervisión regional y modelación del Artico, Atlántico y Pacífico Norte.
9. Priorización del desarrollo tecnológico en los campos de:

   termometría y tomografía acústica;

   mediciones de salinidad;

   boyas de perfilaje;

   vehículos automáticos submarinos

   perfiladores acústicos de corrientes Doppler para despliegue en VOS;

   mejor definición de la cobertura de hielo en las áreas de borde;

   antiensuciamiento (para mejor rendimiento del instrumento);

   óptica y acústica para mediciones biológicas.

Los mares costeros se ven muy influidos por la variación del mar abierto, incluyendo el transporte de calor, salinidad y nutrientes y la surgencia vertical. Los recursos marinos vivos de los mares costeros se ven afectados por fenómenos de mar abierto a gran escala. Entre los ejemplos se incluye El Niño y sus consecuencias masivas en la pesca de muchos países y el gigantesco cambio de régimen en las sardinas y anchovas de muchas pesquerías costeras en los últimas décadas, lo que refleja un forzamiento a escala muy grande. El estudio del Ecosistema de la Corriente de Benguela se centra en este tema.

A su debido momento, cuando los paneles de módulos hayan desarrollado sus planes iniciales, la presente estructural de panel modular del GOOS cambiará para reflejar la estructura temática de este marco de implementación.

El éxito de este marco de implementación y la revisión necesaria del rendimiento del sistema necesario para la Fase 5, piden la provisión de la asistencia estructural adecuada y la experiencia para: (1) realizar la planificación y coordinación adecuadas; (2) asegurar la creación, mantenimiento y promoción de los procedimientos y prácticas operacionales aceptadas internacionalmente; (3) facilitar la formación y conocimiento y creación de capacidades.

Entre los temas clave en la infraestructura resultante se encuentran:

1. El establecimiento de un Centro de Información.
2. El desarrollo de redes para las telecomunicaciones de datos de tiempo real y tiempo casi real, asimilación en modelos y difusión de productos y pronósticos.
3. La negociación de una política de datos conforme a los Principios GOOS (el valor por defecto es la aplicación de las políticas de datos de las organizaciones patrocinadoras).
4. La transferencia tecnológica y la formación para conseguir la creación de capacidad, y la inversión sostenida en la creación de capacidades.

En lo que sigue, el Capítulo 1 define la naturaleza del GOOS. El Capítulo 2 ilustra la guía estratégica para su implementación. El Capítulo 3 establece la base legal, institucional, económica, científica, tecnológica y operacional para GOOS. El Capítulo 4 explica el diseño del GOOS, estudiando los datos y la estrategia de gestión de la información que se está desarrollando en GOOS para generar y distribuir datos, productos y servicios. El Capítulo 5 proporciona un marco para la implementación según se ha resumido más arriba, en base a las consideraciones y conclusiones de los capítulos precedentes, sugiere líneas directrices para el establecimiento de prioridades y recomienda acciones de gran prioridad para un futuro inmediato. Finalmente, el Capítulo 6 utiliza ejemplos para demostrar cómo los precursores tipo GOOS han sido aplicados o se están aplicando con éxito en 6 servicios o programas prototipo físico, químico y/o biológico.

Оффициальный обзор

Планы развития системы *GOOS (the Global Ocean Observing system -* Глобальная система наблюдений океана) на 1998 год показывают, что инвестиции в систему *GOOS* со стороны национальных и международных оперативных агенств, научно-исследовательских институтов, а также со стороны благотворительных фондов, окажутся выгодными для экономического и социального развития в мировом масштабе, при приемлемом уровне затрат и риска.

Инвестиции принесут пользу на уровнях отдельных компаний и юридических лиц, на уровнях стран или государственных организаций, а также на международном или глобальном уровне для лучшего понимания и управления морской окружающей средой, прогнозирования всемирной климатической системы, разработки морских ресурсов, улучшения безопасности мореплавания и уменьшения воздействия таких стихийных бедствий, как например, затопление побережья.

Прогнозирование и информационные данные будут включать в себя такие физические факторы как: штормы, течения, лед и волны, а также живые ресурсы, состояние океанической экосистемы, эрозию и затопление побережья. Реализация программы GOOS зависит от скорейшего наиболее полного использования существующего уровня научных знаний при параллельном ведении дальнейших научно-исследовательских работ, необходимых для того, чтобы система GOOS достигла своей максимальной эффективности и пользы.

Значительная часть мировой экономической деятельности и широкий спектр услуг, эстетические блага и социальные преимущества зависят от эффективного управления морями. Программа GOOS была создана в 1991 году как реакция на стремление многих государств улучшить прогнозирование климатических изменений, управление морскими ресурсами, уменьшить воздействие стихийных бедствий, а также улучшить использование прибрежной зоны и защитить ее окружающую среду. Для многих государств морские ресурсы и услуги составляют от 3 до 5% их Валового национального продукта. А для некоторых государств этот процент еще выше. В некоторых странах получение пищевого белка почти полностью зависит от морских промыслов и от аквакультуры.

Прямую выгоду от применения системы GOOS получит управление береговыми укрепительными сооружениями, портами и гаванями, прибрежными инженерно-техническими сооружениями, а также рыболовство и разведение рыб, выращивание моллюсков, судоходство и проводка судов, добыча нефти и газа на прибрежном шельфе, прокладка кабелей и труб, отдых и туризм. Пользу от применения системы GOOS получат (за счет улучшения прогнозирования сезонной и многолетней климатической изменчивости, на основе наблюдений за океаном) сельское хозяйство и производство пищевых продуктов. Результаты GOOS будут полезны для рационального использования энергии и пресной воды и решения некоторых вопросов здравоохранения (например, борьба с эпидемиями малярии, такими как те, которые были вызваны Эль Ниньо).

Планы развития программы GOOS на 1998 год показывают, что система GOOS может быть создана в ближайшее время, и она начнет производить необходимые информационные данные очень быстро. Эти информационные данные будут продолжать улучшаться, как по объему, по своей географии и по ценности, что может быть достигнуто путем логического и прогрессивного развития науки и оперативных служб. Экономический анализ показывает, что затраты и выгоды от внедрения системы GOOS, скорее всего, будут того же порядка, что и те которые получены от внедрения системы Всемирной службы погоды, той успешной системы, которая обеспечивает все виды прогнозирования погоды.

Общие принципы построения системы GOOS, а также Стратегический план для достижения ее долгосрочных целей, уже были опубликованы, и они в данном Проспекте лишь просто суммируются. Данный Проспект базируется на этих принципах и на Стратегическом плане.

Планирование системы GOOS имеет хорошую основу. Многие страны учредили свои собственные национальные комитеты GOOS внутри министерств или внутри агентств. Сотрудничество спонсорских агентств на уровне ООН (Межправительственная океанографическая комиссия - IOC при ЮНЕСКО, Международной метеорологической организацией - WMO и ЮНЕП) и ICSU, осуществляется с помощью объединенной системы контроля.

Юридическая основа для деятельности системы GOOS определяется различными международными конвенциями и планами мероприятий, включая следующие: Конвенция ООН по морскому праву: Рамочная конвенция об изменениях климата; Конвенция о биологической вариативности; Повестка дня на 21 век (одобренная на Конференции ООН по окружающей среде и развитию в Рио-де-Жанейро в 1992 году); Всемирный план мероприятий по защите морской среды от земной деятельности; Лондонская конвенция о затоплении отходов; Конвенция ООН по морскому праву в части трансграничных рыбных запасов и запасов далеко мигрирующих рыб и управлению ими, а также другие конвенции, которые приводятся в данном Проспекте. Информация, предоставляемая системой GOOS, потребуется государствам для того, чтобы выполнять свои обязательства по данным конвенциям.

Оффициальный обзор

Система GOOS является частью Единой стратегии глобального наблюдения (IGOS), в которой сотрудничают агентства ООН (ЮНЕСКО и ее Межправительственная океанографическая организация - IOC, ЮНЕП, Международная метеорологическая организация - WMO и Продовольственная и сельскохозяйственная организация - FAO) вместе с ICSU и с организациями, отвечающими за сбор информации с помощью спутников (через Комитет по системам надлюдения за Землей). Система GOOS образует морскую составляющую Глобальной системы наблюдения за климатом (GCOS), а также морскую прибрежную составляющую Глобальной системы наблюдения за наземным пространством (GTOS).

Главные цели системы GOOS, как явствует из Раздела 1.3 Плана развития, являются следующими:

1. уточнение видов данных наблюдения за морем, необходимых для всемирных пользователей морской окружающей средой;
2. развитие и претворение в жизнь международной скоординированной стратегии по сбору, обработке и обмену этих данных;
3. содействие созданию продуктов и услуг, базирующихся на этой информации, а также расширение сферы их применения в использовании и защите морской окружающей среды;
4. содействие развитию средств, при помощи которых менее развитые страны могут увеличить свои возможности по приобретению и использованию морских данных в рамках системы GOOS;
5. координация проводимых мероприятий системы GOOS и обеспечение их вхождения в более широкие глобальные наблюдательные системы и стратегии управления окружающей средой.

Система GOOS базируется на прежних инвестициях в океанскую научно-исследовательскую деятельность, океанские технологические системы, включая искусственные спутники наблюдения за Землей, а также на существующих системах наблюдения и прогнозирования.

Научная деятельность на национальном, региональном и всемирном уровнях была крайне необходима для успешной реализации системы GOOS. В частности, глобальные совместные эксперименты такие, как эксперимент TOGA (Тропические океаны и глобальная атмосфера), WOCE (Эксперимент по изучению циркуляции Мирового океана) и продолжающиеся эксперименты GLOBEC (Глобальная динамика океанских экосистем) и CLIVAR (Изменчивость и прогнозирование климата) позволили создать основу глобальных банков данных, а также разработать систему их оперативной обработке, что является крайне необходимым.
Вышеперечисленные, а также другие крупномасштабные научные проекты, потребуются для улучшения работы системы GOOS и для распространения возможности прогнозирования на область химических и биогенных факторов.

Техническую основу системы GOOS составляют ряд испытанных и множество новейших систем приборов для сбора данных в точке наблюдения и средств связи, большое количество наблюдательных станций, расположенных на побережье и на мелководье, и ряд измерительных приборов на борту научно-исследовательских или добровольных и попутных судов. Крайне необходимыми для успешной работы системы GOOS являются наблюдения с искусственных спутников земли за океанским льдом, температурой морской поверхности, цветогаммой океана, изменениями в уровне моря и в топографии поверхности моря, а также наблюдения за ветром, волнообразованием и течениями. Важно, чтобы в будущем все эти виды данных собирались во время запусков стандартных искусственных спутников земли, планируемых для выполнения операционных целей, при оптимальных затратах. Способность системы GOOS быстро превращать полученные наблюдения в полезную информацию зависит, главным образом, от применения мощных компьютеров и самого современного программного обеспечения для моделирования.

В настоящее время существуют различные службы, предоставляющие местные данные или прогнозы для морских операций, как например: данные для обеспечения захода в большой порт, о вредоносном цветении водорослей, о нефтяных пятнах на воде, протяженности морского льда или данные о силе морских течений около платформ для подводной добычи нефти. Данный вид услуг предоставляется как государственными, так и коммерческими организациями. Органы ООН координируют всемирное сотрудничество в наблюдениях за уровнем океана, измерением температуры в его верхнем слое, морской метеорологии, а также некоторых аспектов данных в области биологии, рыболовства и загрязнения окружающей среды. Часть этих данных обрабатывается в реальном времени для обеспечения прогнозирования. Великолепным примером этого может послужить перевод эксперимента TOGA (Тропические океаны и глобальная атмосфера) в операционную наблюдательную систему в тропической части Тихого океана для предсказания событий Эль Ниньо. Очень многому можно поучиться у существующих систем морских измерений и прогнозирования. Система GOOS будет сотрудничать с данными системами и добавлять к ним элементы глобальных наблюдений, непрерывности по времени и возможности применения самых передовых численных моделей.

В настоящее время система GOOS реализуется путем пяти взаимоперекрывающих стадий:

1 планирование системы, включая определение проектной и технической стороны;
2. операционная демонстрация системы и проведение опытных экспериментов;
3. включение в систему приемлемых существующих наблюдательных систем и связанной с ними деятельностью, а также новых видов деятельности, которые могут быть реализованы в настоящее время для того, чтобы составить Первичную наблюдательную систему

GOOS;
4. постепенное операционное введение в действие «постоянной» или непрерывно действующей Глобальной системы наблюдений океана;
5. непрерывная оценка и улучшение работы как индивидуальных аспектов, так и всей системы в целом.

Стадия 1. Первая Стадия уже хорошо разработана. Первичное формирование системы GOOS разрабатывается консультативными органами, занимающимися: (i) климатом; (ii) прибрежными морями; (iii) живыми морскими ресурсами; (iv) здоровьем океана (т.е. его загрязнением); и (v) морскими метерологическими и океано-графическими службами. Данные консультативные органы подчиняются Руководящему комитету системы GOOS (GSC), отвечающему за проектирование и реализацию системы GOOS. Межправительственный комитет (I-GOOS) оказывает помощь в получении межгосударственной поддержки и одобрений для проектирования системы и ее реализации. Комитет по оказанию помощи развивающимся странам в увеличении вкладов и возможности использования результатов GOOS отчитывается перед GSC и I-GOOS.

В течение Первой Стадии проводилось изучение экономических, социальных и научных запросов как отдельных стран, так и регионов. Велась оценка данных приоритетов в отношении технически осуществимых в настоящее время наблюдений, а также тех наблюдений, которые требуют дальнейших научно-исследовательских и технических разработок. Эти разработки ведут к созданию первичной системы наблюдения GOOS, а также к определению потребностей в управлении и обработки данных.

Во время Ассамблеи МОК 1999 года государствам-членам будет предложено официально принять Принципы системы GOOS. Национальные и региональные оперативные агенства получат возможность предоставить некоторые из своих имеющихся операционных ресурсов системе GOOS для ее более успешной реализации. Данная работа может быть скоординирована через национальные комитеты системы GOOS.

Стадия 2 началась с опытных проектов для проверки работы системы GOOS в конкретных регионах, а также для отлаживания работы подсистем GOOS. Опытный проект NEAR-GOOS охватывает северо-восточные моря Азии. Первоначально он фокусируется на развитии обмена данными между партнерами по проекту, а также на формировании сообщества пользователей информации. В будущем данный проект будет разрабатывать способность цифрового моделирования и прогнозирования. Сейчас проект, главным образом, работает с физическими данными. В Европе Ассоциация EuroGOOS, состоящая из 30 оперативных агенств из 16 стран, сводит воедино исследователей и операторов для создания более эффективных и успешных систем наблюдения за Арктикой, Балтийским и Средиземным морями и северо-западным шельфом континента, и для определения потребностей в научных исследованиях и технологиях для придания системе GOOS большей эффективности. В работе данной Ассоциации на одном из первых мест по значимости стоит моделирование океана и прогнозирование, а также улучшение состояния обмена данными. Предлагаемый Проект по Атлантике предназначен для улучшения информации по пограничным условиям для подгона моделей к европейским прибрежным морям. В то время как изначально система EuroGOOS сосредотачивается на получении физических параметров, химические (нитраты) и биологические (планктон) параметры также играют значительную роль в программе EuroGOOS.

Значительный интерес к разработке ряда других региональных проектов проявили государства: (i) западной части Индийского Океана (WIOMAP); (ii) юго-восточной Азии (SEA-GOOS); (iii) Средиземноморья (MED-GOOS); и юго-западной части Тихого Океана (Pacific-GOOS).

Проекты, связанные с демонстрацией современной техники, включают PIRATA (Сбор информации при помощи исследовательских экспериментальных буев в тропической части Тихого Океана) и GODAE (Глобальный эксперимент по усвоению океанических данных). Проект PIRATA продемонстрирует ценность измерений, полученных в экваториальной части Атлантики для прогнозирования климатических изменений. Проект GODAE включит в себя и обобщит данные, собранные от приборов, расположенных in situ и на спутниках в реальном времени, в общую модель мирового океана для воссоздания циркуляции океана во временном масштабе (в течение нескольких дней) и в пространственном масштабе (на несколько десятков километров) для того, чтобы продемонстрировать жизнедеятельность системы GOOS в данной области.

Стадия 3 началась с создания Первичной системы наблюдения GOOS (GOOS - IOS) на основе ранее существоваших систем наблюдения, каждая из которых будет продолжать обслуживать своих постоянных клиентов. В эти системы входят: программа измерения верхнего слоя океана с попутных судов (SOOP); сеть добровольных судов наблюдения за метеорологическими наблюдениями (VOS); заякоренные и дрейфующие буи, координированные Комитетом сотрудничества по сбору сбору данных от буев (DBCP); буи в тропической части мирового океана (TAO), расположенные для отслеживания событий Эль Ниньо в экваториальной части Тихого Океана; сеть измерителей уровня моря в Глобальной системе наблюдения за уровнем моря (GLOSS); данные Всемирной программы измерения температуры и солености морской воды (GTSPP); информация Всемирного мониторинга коралловых рифов (GCRMN); и обмен сообщениями, полученными по всемирной сети Интернет и Всемирной теле-коммуникационной системе (GTS) Международной метеорологической организации (WMO).

Оффициальный обзор

Данные измерительные системы, в основном, занимаются сбором физических наблюдений, за исключением программы Всемирного мониторинга коралловых рифов (GCRMN). В настоящее время рассматривается вопрос, какая конкретно химическая и биологическая информация требуется, и каким образом интегрировать их с физическими данными. Живые морские ресурсы существуют, главным образом, в прибрежной зоне, однако требования к мониторингу живых ресурсов и экосистем прибрежных морей остаются в стадии разработки.

Задачей является разработка систематизированного и единого подхода к прибрежному мониторингу и прогнозированию на основании нужд прибрежных государств целей поддерживаемых проектов. Примерами рассматриваемых в настоящее время существующих систем наблюдения могут служить программа Межгосударственной океанографической комиссии (IOC) Вредоносного цветения водорослей (HAB); Международная программа наблюдения за моллюсками; Система мониторинга загрязнения морской среды (MARPOLMON) и программа Непрерывного наблюдения за планктоном (CPR).

Стадия 4 будет включать продолжение интеграции других компонентов, подобных перечисленным, а также новых систем с целью увеличения числа переменных, включая химические и биологические факторы, относящихся к поддерживанию в здоровом состоянии прибрежной зоны, включая живые морские ресурсы и экосистемы. Максимальная выгода от измерения и моделирования прибрежной зоны произойдет при соединении крупномасштабных временных и пространственных океанских моделей с гнездовыми моделями на континентальном шельфе. Это придаст прогнозированию больший временной аспект в сочетании с детальными местными биологическими данными.

Реализация программы будет идти двумя параллельными путями:

1. мониторинг прибрежной зоны и шельфа, а также прогнозирование;
2. мониторинг открытого океана и прогнозирование.

В обоих случаях предлагается, чтобы инвестиции фокусировались на те действия, которые:

1. будут сильно способствовать предоставлению данных и информации, в которых имеется необходимость;
2. известны тем, что они выполнимы, и, таким образом, вероятнее всего будут успешными;
3. продолжают и усиливают те действия, которые уже доказали свою ценность, а также поощряется их копирование или расширение с малой степенью риска;
4. включают более значительные демонстрационные проекты, имеющие поддержку общества;
5. способствуют выполнению межгосударственных конвенций и соглашений.

Говоря о 1-ом пути (мониторинг прибрежной зоны), будет необходимо выполнить следующие действия:

1. поддержка существующих программ GOOS-IOS;
2. разработка и применение автоматических биологических и химических датчиков и методов, необходимых для реализации единых наблюдательных систем, включая физико-химико-биологические данные, собранные непосредственно in situ и на расстоянии, данные телеметрии, ассимиляции данных и моделирования;
3. разработка наблюдательных программ достаточной продолжительности по времени, по пространству, по разрещающей способности и по синоптической изменчивости для того, чтобы сделать возможным краткосрочный прогноз, прогнозирование и прогнозирование на более долгий период;
4. расширение географии наблюдательных систем для включения в него районов с недостатком данных, и позволяющие производить сравнительный анализ прибрежных систем;
5. создание и расширение оперативного моделирования для включения более широкого круга морского моделирования и прогнозирования;
6. создание улучшенных баз данных по охране окружающей среды, включая батиметрические данные высокой точности, для поддержания численого моделирования районов шельфа;
7. реализация основных приоритетов и достижение основных целей в региональных и национальных программах GOOS;
8. передача опыта, там, где это будет уместно, между регионами, а также между регионагьными программами GOOS.

Говоря о 2-ом пути (мониторинг открытого океана), будет необходимо выполнить следующие действия:

1. провести Эксперименты с моделированием систем наблюдения (OSSEs) для того, чтобы оказать помощь при составлении приоритетности в проектировании системы GOOS для сезонного и годового прогнозирования;
2. составление приоритетности и реализация систем мониторинга in situ, которые дополняет космический компонент системы наблюдения;
3. определение вкладов, необходимых для поддержания и адаптации существующих систем;
4. учреждение Глобального эксперимента по ассимиляции океанических данных (GODAE) в качестве единых рамок для сконцентрированных усилий по вовлечению в работу исследователей и оперативных органов;
5. постепенное увеличение мощностей наблюдательных систем при помощи (i) добавления новых или усовершенствованных датчиков (например, оптических, акустических, датчиков солености воды) на существующие платформы; (ii) оперативная поддержка проекта PIRATA (Сбор информации при помощи

исследовательских экспериментальных буев в тропической части Тихого Океана) после 2000 года; (iii) иные раширения сети буев, расположенных в тропической части мирового океана (TAO), (например, для района Индийского Океана).

6. поддержание важных временных рядов;
7. поддержка проектов, ведущихся в рамках WOCE, JGOFS, CLIVAR и GLOBEC, которые способствуют развитию системы GOOS;
8. поддержка проектов регионального мониторинга и моделирования проектов в Арктике, в Атлантическом Океане и Северной части Тихого Океана;
9. определение приоритетов в развитии техники в таких отраслях как:
   - акустическая термометрия и томография;
   - измерение солености воды;
   - поплавковые измерители профилей;
   - подводные автономные самодвижущиеся аппараты;
   - акустические измерители течений методом Допплера на добровольных судах наблюдения;
   - лучшее определение ледового покрова у ледовой кромки;
   - предохранение от обрастания (для улучшения работы приборов);
   - оптические и акустические приборы для биологических измерений.

На прибрежные моря оказывает сильное влияние изменчивость открытого океана, включая перенос тепла, солей, питательных веществ, и вертикальный апвеллинг. На живые морские ресурсы прибрежных морей оказывают влияние крупно-масштабные явления открытого океана. Среди примеров можно привести события Эль Ниньо, и их колоссальное влияние на рыболовство многих стран, а также огромные смещения в режиме поведения сардин и анчоусовых рыб за последние десятилетия во многих прибрежных промысловых зонах, что является отражением крупномасштабного воздействия. Данный вопрос изучается проектом по Крупной морской экосистеме бенгуельского течения.

Через определенное время, когда существующие органы закончат разработку своих первоначальных планов, современная модульная структура системы GOOS претерпит изменения для того, чтобы отражать тематическую структуру в рамках данной реализации.

Достижение рамок данной реализации, а также необходимый обзор характеристик, нужный для стадии 5, требует предоставления соответствующей структурной поддержки и знаний для: (i) проведения соответствующего планирования и координации; (ii) обеспечения создания, поддержания и пропаганды международно-признанных операционных процедур и действий; (iii) облегчения процесса обучения, информированности и наращивания мощностей.

В конечной инфраструктуре ключевыми проблемами являются следующие:

1. создание Информационного Центра;
2. развитие телекоммунникационных систем передачи данных в реальном и почти-реальном маштабах времени, ассимиляция информации в модели и рапространение продуктов и прогнозов.
3. обсуждение политики предоставления данных в соответствии с Принципами системы GOOS (в противном случае будет применена политика предоставления данных, существующая в организации-спонсоре);
4. передача технических средств и обучение для целей наращивания мощностей, а также последующие инвестиции для дальнейшего их увеличения.

В последующем, в Главе 1 описывается общая структура системы *GOOS*. Глава 2 иллюстрирует стратегические пути для ее реализации. Глава 3 излагает юридическую, экономико-правовую, экономическую, научную, техническую и операционную основу системы *GOOS*. Глава 4 показывает устройство системы *GOOS* в отношении стратегии управления базами данных и информации, разрабатываемых в системе *GOOS* для накопления и рапределения информации и данных. Глава 5 раскрывает рамки для реализации всего упомянутого выше на анализа и выводов предыдущих глав. Также глава предлагает руководство для установления порядка очередности и первоочередности реализации системы на ближайшее время. И, наконец, Глава 6 использует примеры для демонстрации того, каким образом предшественники системы *GOOS* применялись, или успешно применяются в настоящее время, в шести прототипах физических, химических и/или биологических услуг или программ.

1
THE NATURE OF THE GLOBAL OCEAN OBSERVING SYSTEM

1.1 The Vision

A world where the information needed by governments, industry, science and the general public to deal with marine related issues, including the effects of the ocean upon climate, is supported by a unified global network to systematically acquire, integrate and distribute oceanic observations, and to generate analyses, forecasts and other useful products.

THE NATURE OF THE GLOBAL OCEAN OBSERVING SYSTEM

Rationale

The Prospectus for the Global Ocean Observing System (GOOS) 1998 shows that investment in GOOS by national and international operational agencies, by research organisations, commercial companies and by aid agencies, will produce economic and social benefits which are valuable on a global scale, and at a cost and risk which are acceptable.

The benefits accrue at the levels of individual companies and entities; at the levels of countries and government agencies; and internationally or globally in the form of better understanding and management of the marine environment, forecasting the global climate system, exploitation of marine resources, and improved management of safety at sea and mitigation of disasters such as coastal floods.

Predictions and information products will include the physical factors such as storms, currents, ice and waves, as well as living resources, health of the oceanic ecosystem, coastal erosion and flooding. Implementation of the GOOS relies upon exploiting the existing level of scientific knowledge as rapidly as possible, while pursuing in parallel further research which will be needed for GOOS to reach its maximum efficiency and usefulness.

A significant part of world economic activity and a wide range of services, amenities and social benefits depend upon efficient management of the sea. The GOOS was created in 1991 in response to the desire of many nations to improve forecasts of climate change, management of marine resources, to mitigate natural hazards, and improve utilisation and environmental protection in the coastal zone. For many countries marine resources and services provide 3-5% of their Gross National Product. For a few it is much higher. Some countries depend almost entirely upon marine fisheries and aquaculture for food protein.

Direct beneficiaries of the services produced by GOOS are the managers of coastal defences, ports and harbours, coastal civil engineering, fishing and fish farming, shellfish farming, shipping and ship routeing, the offshore oil and gas industry, cable- and pipe-laying, recreation and tourism. Indirect beneficiaries, through improved forecasting of seasonal and multi-year climate variability based on ocean observations, include agriculture and food production, and the management of energy, fresh water, and public health (e.g. for epidemics of malaria such as those associatedwith El Ninõ events).

The GOOS Prospectus 1998 shows that GOOS is achievable on a reasonable timescale, will start to produce useful products very quickly, that the products will continue to improve in scope, geographical coverage, and value, and that this can be achieved by logical and progressive development from the present state of science and operational services. Economic analysis suggests that the costs and benefits of the GOOS are likely to be similar to those of the World Weather Watch, the successful system that underpins all weather forecasting. The overall Principles upon which the GOOS is designed, and the Strategic Plan for achieving its long term goals have been published elsewhere, and are summarised in the Prospectus. This Prospectus is based on the Principles and the Strategic Plan.

The planning of GOOS is well-founded, and many countries have set up inter-departmental or inter-agency national GOOS Committees. There is a collaborative supervisory system linking the sponsor agencies at the UN level (IOC of UNESCO, WMO, and UNEP) and ICSU.

The legal basis for proceeding is defined by various international Conventions and Action Plans, including: the Convention on the Law of the Sea; the Framework Convention on Climate Change; the Biodiversity Convention; Agenda 21 (agreed at the United Nations Conference on Environment and Development in Rio in 1992); the Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities; the London Dumping Convention; the Agreement on Highly Migratory and Straddling Stocks; and others summarised in this Prospectus. The information provided by the GOOS will be needed by governments to meet their obligations under these Conventions.

The GOOS is part of an Integrated Global Observing Strategy (IGOS) in which the UN Agencies (UNESCO and its IOC, UNEP, WMO, and FAO) are working together and with ICSU and the satellite agencies (through the Committee on Earth Observing Systems). The GOOS forms the ocean component of the Global Climate Observing System (GCOS), and the marine coastal component of the Global Terrestrial Observing System (GTOS).

The Primary objectives of GOOS, simplified from the statement in Section 1.3 of the Prospectus are:

1.2
THE NATURE OF THE GLOBAL OCEAN OBSERVING SYSTEM

Rationale

1. to specify the marine observational data needed to meet the needs of the world community of users of the oceanic environment;
2. to develop and implement an international co-ordinated strategy for the gathering, acquisition, and exchange of these data;
3. to facilitate the development of products and services based on the data, and widen their application in the use and protection of the marine environment;
4. to facilitate the means by which less-developed nations can increase their capacity to acquire and use marine data according to the GOOS framework;
5. to co-ordinate the ongoing operations of the GOOS and ensure its integration within wider global observational and environmental management strategies.

The GOOS is based on the past investment in marine scientific research, marine technological systems including earth observing satellites, and the existing operational observing and forecasting services.

Scientific investment at the national, regional, and global level has been essential to make GOOS possible. In particular, global co-operative experiments such as the Tropical Ocean Global Atmosphere (TOGA) experiment, the World Ocean Circulation Experiment (WOCE), and the ongoing Global Ocean Ecosystem Dynamics (GLOBEC) and Climate Variability and Predictability (CLIVAR) provide the basis of global data sets, and rapid processing of global data which are essential. These and other large scale scientific projects will be required to improve the performance of GOOS, and to extend the range of its predictive ability, particularly in the field of chemical and biological factors.

The technological basis of GOOS consists of a variety of proven and novel *in situ* instruments and communication systems, a large number of coastal and shallow water observing stations, and a number of measuring techniques based on research ships or voluntary observing ships and ships of opportunity. Satellite observations of sea ice, sea surface temperature, ocean colour, variations in sea level and sea surface topography, wind, waves, and currents are essential for the success of the GOOS. It is important that these types of data should be available in future from standardised satellite missions which are planned at optimum cost for operational purposes. The ability of GOOS to convert observations rapidly into useful information depends critically upon the use of powerful computers and very sophisticated modelling software.

Many services already exist which provide local data and forecasts for marine operations such as entry to a large port, toxic algal blooms, oil slicks, the extent of sea ice, or the strength of currents near an oil rig. These services are provided by both governmental and commercial organisations. UN Agencies co-ordinate global collaboration in observations of sea level, upper ocean temperature, marine meteorology, and aspects of biology, fisheries, and pollution data. Some of these data are processed in real time to support forecasts. A supreme example of this has been the transition of the TOGA experiment into an operational observing system in the tropical Pacific to predict El Ninõ events. There is a great deal to be learnt from the experience of existing marine measuring and forecasting services, and GOOS will collaborate with them, and add the elements of complete global coverage, temporal continuity, and access to the most advanced global computer models.

The GOOS is being implemented through 5 overlapping phases:

1. planning, including design and technical definition;
2. operational demonstrations and pilot experiments;
3. incorporation of suitable existing observing and related activities and new activities that can be implemented now to constitute the GOOS Initial Observing System;
4. gradual operational implementation of the 'permanent' or ongoing Global Ocean Observing System;
5. continued assessment and improvement in individual aspects and in the entire system.

Phase 1. The first phase is well advanced. The initial shape of the GOOS is being developed by advisory panels dealing with: (i) climate; (ii) coastal seas; (iii) living marine resources; (iv) the health of the ocean (i.e. pollution); and (v) marine meteorological and oceanographic services. These panels report to the GOOS Steering Committee (GSC), that is responsible for the design and implementation of the GOOS. An Intergovernmental Committee (I-GOOS) assists in gaining intergovernmental support and approval for the design and implementation. Building the capacity of developing nations to contribute to and benefit from the GOOS is the responsibility of a Capacity Building Panel reporting to the GSC and I-GOOS.

During Phase 1 there have been studies of the economic, social, and scientific requirements of different countries and regions, and an assessment of these priorities against those observations which are already technically feasible, and those which require further research or technical development. These considerations lead to the initial observing system of GOOS, and an outline of the data management and data processing needs.

During the 1999 Assembly of IOC Member States will be

European Research Satellite-1

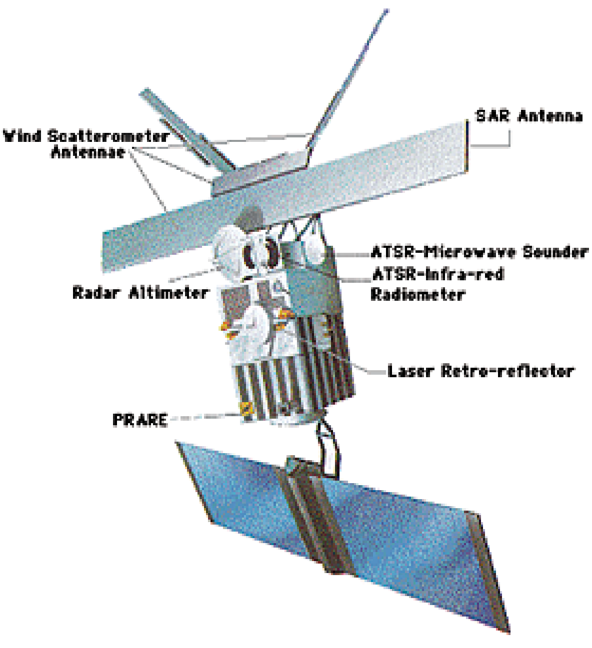
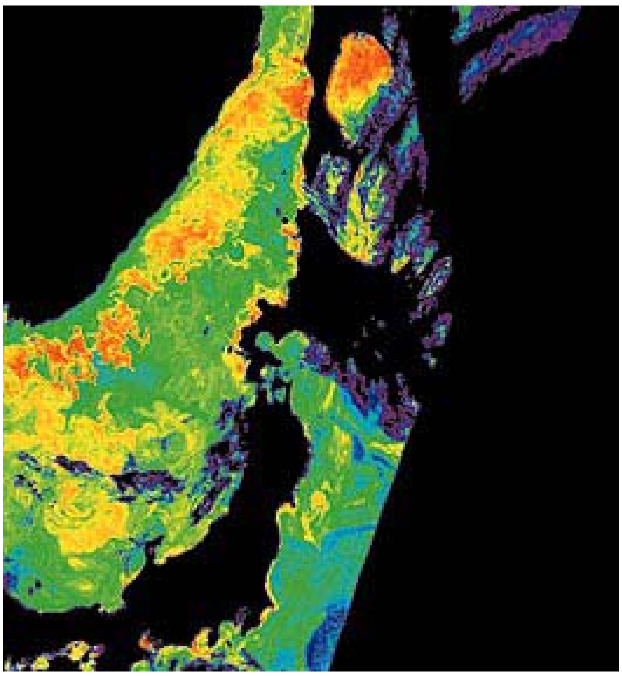
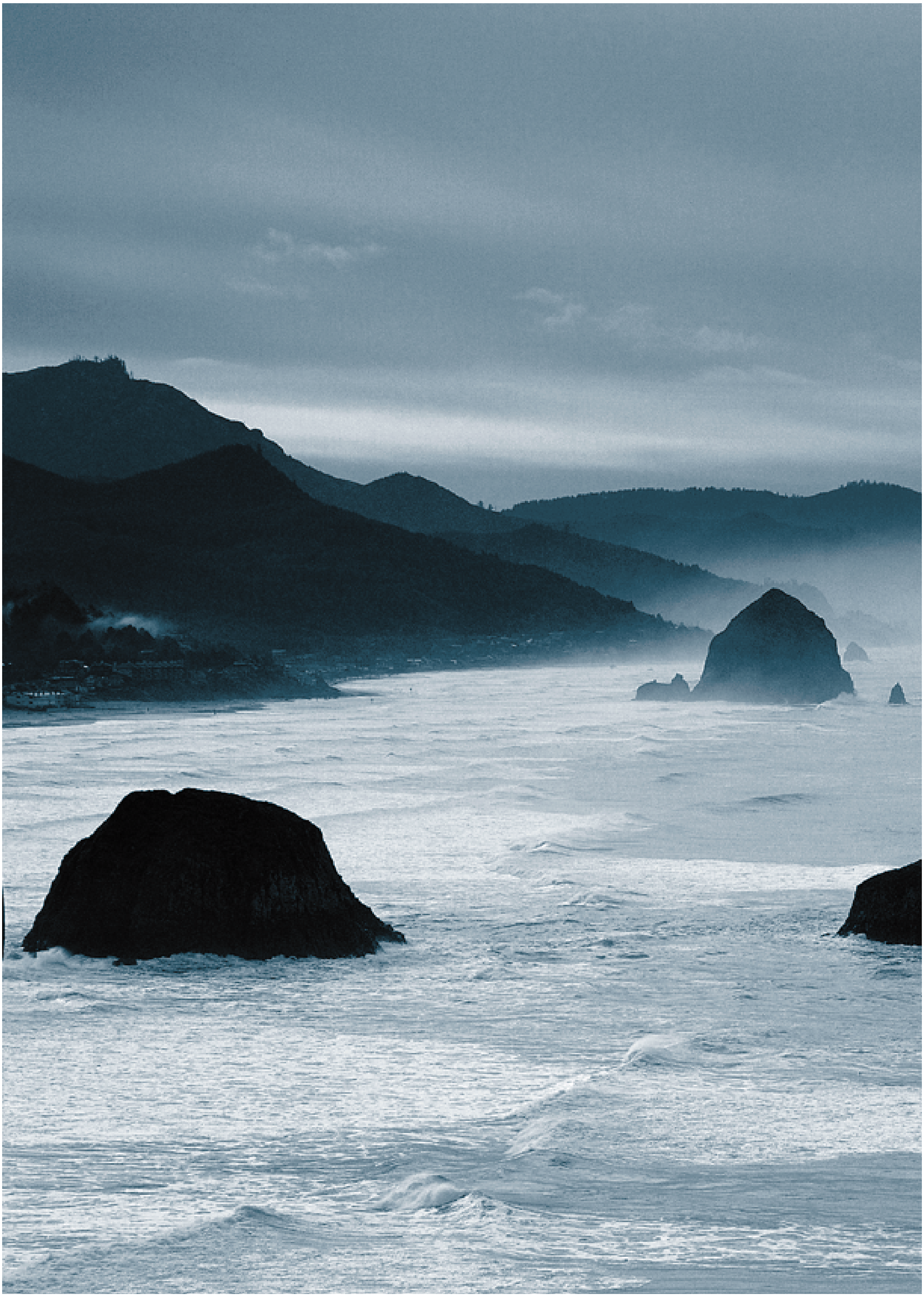


Image of the seas around Japan obtained with the ocean colour instrument (OCSTS) on ADEOS-1



1.2
THE NATURE OF THE GLOBAL OCEAN OBSERVING SYSTEM

Rationale



invited to formally endorse the Principles of GOOS. National and regional operational agencies will have the opportunity to commit certain of their current operational resources to the GOOS to enhance its implementation. Such participation can be co-ordinated through national GOOS committees.

Phase 2 has begun with pilot projects to test the operation of the GOOS in specific regions, and to refine the GOOS subsystems. The NEAR-GOOS Pilot Project covers North East Asian seas. It focuses initially on developing data exchange between its partners, and on building the user community. In the future it will develop a numerical modelling and forecasting capability. The initial focus is primarily on physical data. In Europe, the EuroGOOS Association of 30 operational agencies from 16 countries is bringing researchers and operators together to create more efficient and effective observing systems for the Arctic, Baltic, Mediterranean, and North West Shelf of the continent, in the process identifying the needs for research and technology to make GOOS more effective. Ocean modelling and forecasting is high on their agenda, along with improved data exchange. An Atlantic-scale project is proposed to provide improved boundary conditions for the forcing of models for European coastal seas. While the initial focus of EuroGOOS is on physical parameters, chemical (nutrient) and biological (plankton) parameters also feature prominently in the EuroGOOS programme.

[1]A beneficial service is one whose value to users exceeds the full cost of its production by a significant margin, where both costs and benefits are widely defined and established on a common basis.

[2] Page 4, (IOC, 1996a)

The Overall Objectives of the GOOS[2]

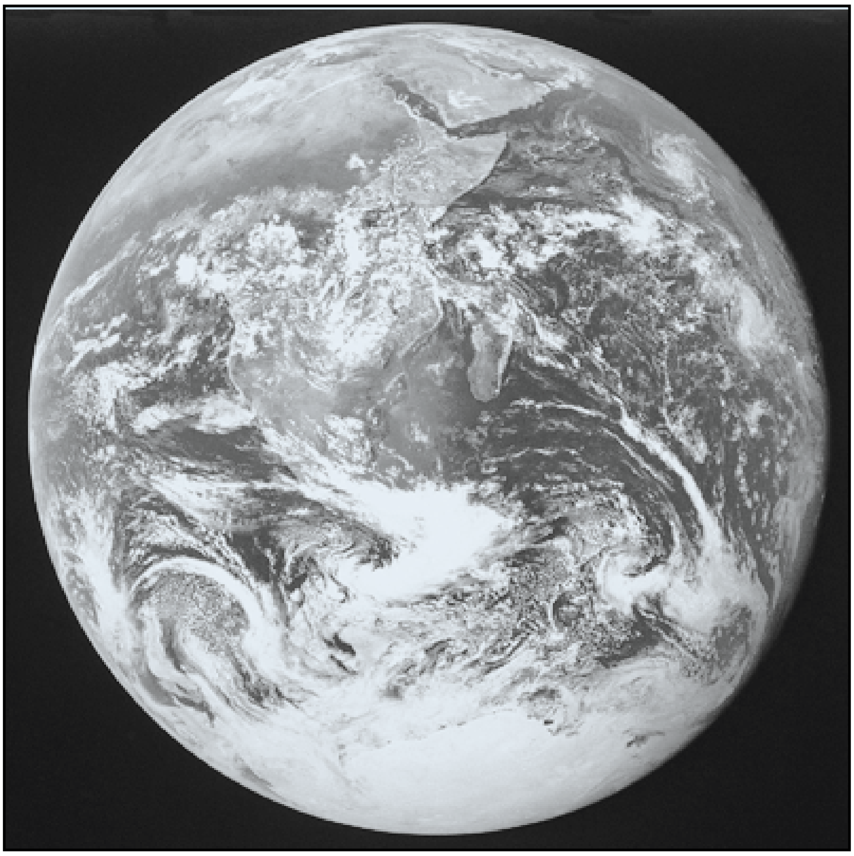
1. **To specify in terms of space, time, quality and other relevant factors the marine observational data needed on a continuing basis to meet the common and identifiable requirements of the world community of users of the oceanic environment.**

2. **To develop and implement an internationally co-ordinated strategy for the gathering, acquisition and exchange of these data.**

3. **To facilitate the development of uses and products of these data, and encourage and widen their application in use and protection of the marine environment.**

4. **To facilitate means by which less-developed nations can increase their capacity to acquire and use marine data according to the GOOS framework.**

5. **To co-ordinate the ongoing operations of the GOOS and ensure its integration within wider global observational and environmental management strategies.**



1.3
THE NATURE OF THE GLOBAL OCEAN OBSERVING SYSTEM

Scope and characteristics

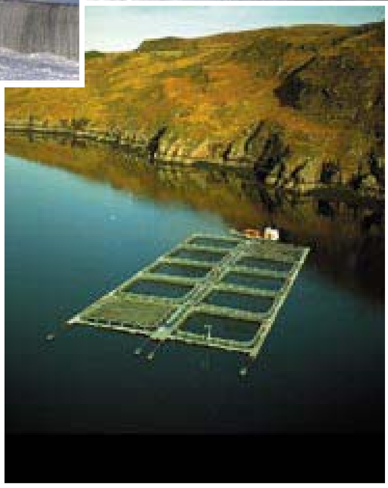
1.3.1 GOOS Products and services

A broad portfolio of products and services will be created by this Global Ocean Observing System. Some will be provided for the public good, in order to safeguard life and property for example, and to protect marine ecosystems. As in the case of weather services, these will be funded by governments or their agencies on behalf of the public and made freely available. Governments will also fund information services that enable them to create, and then monitor, the effectiveness of their environmental, health and marine resource policies and regulations. Some services will be provided on a commercial basis, in order to improve the efficiency and effectiveness of the day-to-day operations of specific industries. Some will allow the design of structures, such as off-shore rigs or sea defences, to be optimised in terms of cost and safety.

To improve local flood defences, and to manage ports and harbours efficiently, coastal zone and port managers need to know how water levels are varying in their area. Water levels may vary because of tides, changes in sea level caused by climate change, surges caused by storms, or changes in wave height, all of which may be independent but also may be combined. All can be monitored, modelled, and forecast.

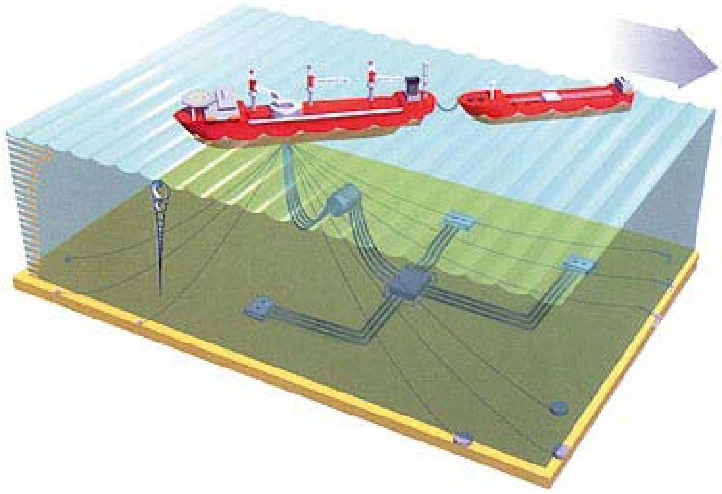
National agencies and regulatory authorities, both individually and regionally need to know the scale and effects of contaminant discharge into coastal areas. Sequestration of chemicals by particles, the production of authigenic compounds and subsequent sedimentation means that what is discharged from the shores or into rivers does not simply pass through the coastal zone into the deep ocean. It is possible, using physical and geochemical models, augmented by measurements, to determine local trapping and storage and the net efflux across the continental shelf from estuaries and the nearshore environment. Such predictive systems need to be able to deal with point and distributed sources and with gradual and episodic changes in forcing functions.

The growth in ocean trade, the increasing automation of ships, and the development of super-giant bulk and oil carriers demands much improved planning of ocean routes to take advantage of knowledge of the changing positions and strengths of ocean currents and the eddies and storm tracks with which they are associated, as well as the likely occurrence of unusually high waves. This demand greatly improved now-casts of ocean conditions and numerical weather forecasts.

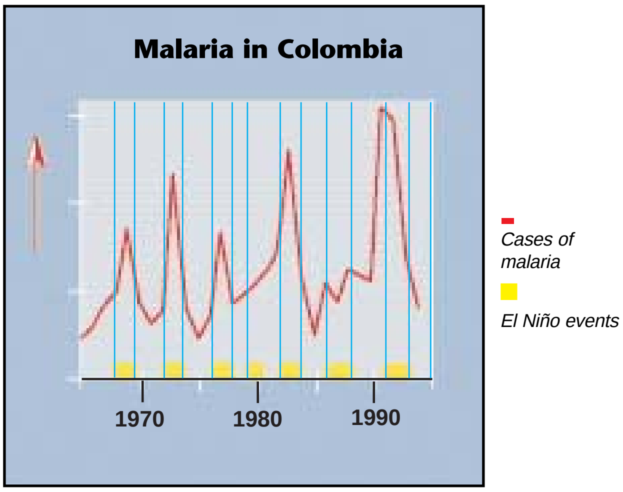


Those concerned with the harvest and conservation of living marine resources need operationally useful information on changes in the state of those resources and the ecosystems in which they exist, for example to be able to assess present stocks and predict their future states, and their vulnerability to forcing by changes in climate, fishing pressure, pollution, or the incidence of harmful algal blooms.

The oil industry is exploring and beginning to exploit reserves below 1000 metres water depth – on both the continental shelf and slope. New engineering techniques are having to be developed to cope with often vigorous and rapidly changing regimes. For design purposes, detailed oceanographic and meteorological data are required to assess operability and extreme loads on floating production systems. For day to day operations such data are required for vessel selection, the use of Remotely Operated Vehicles, riser deployment and ship loading.



Climate also affects the demand for energy, so major energy suppliers need accurate forecasts of how long and cold winter conditions are likely to be year-to-year for a decade or more ahead. Similar information can be used by farmers to assess changes in the length of the growing season.



The availability of skillful seasonal predictions can have a profound effect on the efficiency of agriculture and management of food stocks. Such predictions invariably depend upon complex interactions between the atmosphere and oceans. Measurement and modelling of both components and exchanges between them are essential if reliable predictions are to be made. The most dramatic example of such an interaction and predictive service is to be found in connection with the tropical Pacific ENSO phenomenon, but other links between SST and rainfall have enabled seasonal predictions for the Sahel.

Climatic factors have a major influence on the emergence and re-emergence of infectious diseases, particularly those that are transmitted by insect vectors. In general, rising temperatures escalate disease transmission by extending the geographic range of vectors and shortening the incubation period in the insect host. A direct link has been established between malaria in tropical regions and El Niño events (Poveda and Rosa, 1996). It is becoming increasingly apparent that seasonal or interannual forecasts, based in part on GOOS data, may be useful for health care practitioners in advising them when epidemics of particular diseases are likely to break out, so that appropriate vaccines can be stock-piled and healthcare warnings issued.

1.3
THE NATURE OF THE GLOBAL OCEAN OBSERVING SYSTEM

Scope and characteristics

1.3.2 Relationships to other observing systems

It is clear that some of the important benefits of the GOOS will be realised outside the marine environment; typically in improved climate predictions, often very distant from where particular observations are made. The examples also emphasise that the GOOS is only one of the sources of the required information. Other globally co-ordinated observing and processing systems exist or are being set up to provide related information on the basis of a particular focus, source of expertise or need. The World Weather Watch of the World Meteorological Organization and the Global Terrestrial Observing System (GTOS) have a focus that is primarily concerned with the atmosphere and land surface respectively. The Global Climate Observing System (GCOS) must take a comprehensive view of measurements and their processing related to the atmosphere, oceans, cryosphere and land surface as necessary to provide climate descriptions and prediction.

Some of the resulting arrangements for optimising the various observing systems are straightforward. For example, the oceanic interests of the GCOS are synonymous with the climate interests of the GOOS so that joint sponsorship of planning and implementation of that component has been the obvious way to proceed from the outset. Similarly, satellites provide useful platforms for monitoring atmosphere, land, cryosphere and oceans, so close co-ordination of the space agencies' plans for Earth observation is sensible and being carried out under the auspices of the Committee on Earth Observation Satellites (CEOS). Through the creation of an Integrated Global Observing Strategy (IGOS), attempts are being made to achieve a common view of needs across both satellite-based and *in situ* observing systems.

Many of the numerical models, that will deliver the benefits of investment in observing systems, are coupled and depend upon data from a wide range of sources. Therefore, data and information management must be planned and implemented in a coordinated manner; a Joint Data and Information Panel (JDIMP) has been created for this purpose. Current coordination arrangements are summarised in section 3.2.1.and brief descriptions of the key stakeholders and history of the development of the GOOS are to be found in annex 1.

1.3.3 The Global Dimension

GOOS necessitates globalisation, in the same way that numerical weather forecasting depends upon global models to produce long range and precise forecasts at the local scale. Modelling events in any area depends upon changing conditions at the boundary of that area. Even if those conditions can in principal be modelled and predicted, then there are still open boundaries with unknown conditions at the boundary of the next larger region. The system becomes closed and constrained when there is a global model. GOOS therefore must include global scale coupled ocean and atmosphere models, to provide the boundary conditions and long time scales for smaller regional models.

1.3.4 GOOS measurements

A measurement will be considered to be part of the GOOS if it is part of a long-term, systematic effort required to sustain a beneficial service and is designed to establish the selected properties of a saline body of water. Thus, a routine measurement of wave height or wind could form part of the GOOS; although the latter is a measurement of the atmosphere, it allows sea state to be inferred directly. A single, isolated cruise of a research vessel would not form part of the GOOS but a commitment to sustain a particular line of sub-surface temperature profiles, through the Ship-Of-Opportunity-Programme (SOOP) – paragraph 3.6.2 – would do so.

Elements of the GOOS exist today in the form of partially co-ordinated, local and temporary data capture and processing initiatives, often implemented as part of a research and development programme to investigate particular problems, to detect biological or chemical anomalies or to test a new technology. Elements of the observing system installed for the TOGA research programme, such as the Tropical Atmosphere Ocean (TAO) array, are an example of the former. Some physical data, mainly relevant to the upper levels of the ocean, are gathered and processed on an operational basis, e.g. the temperature and salinity data captured by the SOOP of the Integrated Global Ocean Services System (IGOSS) and the meteorological observations made by the Voluntary Observing Ships (VOS) of WMO Members. Physical, chemical and biological data are collected to aid national coastal zone or fisheries management and to assess the state of the marine environment. Some monitoring is undertaken commercially, particularly to aid offshore operations in the oil and gas industries.

1.4.1 Design Principles

In order to achieve the necessary coherence and meet the objectives set out above, a set of principles have been agreed to guide the design of the GOOS and its components (IOC, 1998a):

D1. The GOOS is based on a plan designed to meet defined objectives on the basis of user needs.
This principle confirms that the GOOS is a planned system from its conception and not simply an opportunistic assembly of whatever ocean observations are offered by participating countries. It also confirms that services will be designed to meet the needs of identified customers or users (including those needs specified by governments to deliver public goods or deal with market failure).

D2. The design assumes that contributions to the GOOS are long-term and systematic.
The GOOS is founded on the concept of systems that are maintained, updated and operated so as to sustain operational services, as is the case for those systems that sustain operational meteorology.

D3. The design will be reviewed regularly in the light of changing requirements, research results, technical advances and system performance.

D4. The design allows for flexibility of technique, provided that standards adequate for the purpose intended are maintained.

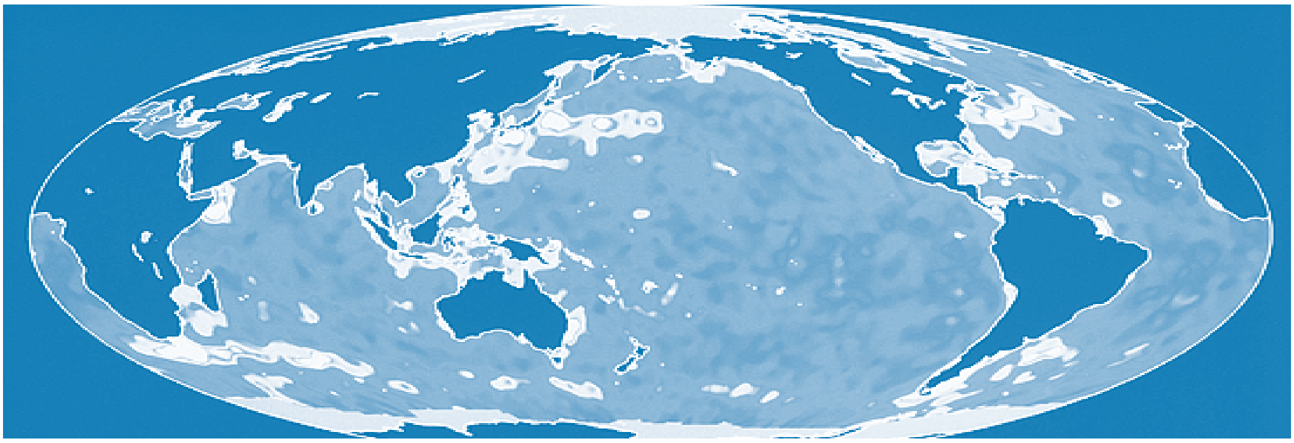
D5. The GOOS is directed towards global problems and/or those ubiquitous problems benefiting from global observing systems. There is a limitless range of needs for observation of the marine environment on all scales from the microscopic to the global. Not all of these will benefit from the involvement of the GOOS. It is the subset of needs that is widespread and gains economy of scale from being tackled in a collective and common manner, that is the subject of the GOOS.

D6. The design covers the range of activities from data capture to the provision of end products and services. This is a commitment to an end-to-end system design, encompassing the capture of data and their timely and reliable processing through to the delivery of credible information services. Serendipitous use of data and products will also be encouraged.

D7. The management, processing and distribution of data will follow a specified data policy.
It is recognised that international agreement on details of the policy may take some time to negotiate. As a practical basis for progress, the current GOOS data policy reflects the common elements of the data policies of its sponsors. Participants are encouraged to regard the GOOS as a global system for their collective benefit and to allow their data to be exchanged freely to the greatest degree possible.

D8. The design takes into account the existence of systems outside the GOOS that can contribute to and/or benefit from the GOOS. A cornerstone of the the GOOS development is that it will be built to the greatest extent possible upon existing national, regional and global systems of observation and data management. This is also a commitment to coexistence and collaboration, to gain mutual benefit from other disciplines and investments, as discussed in paragraph 1.3.

D9. The design takes into account quality assurance procedures. This is a commitment to a level of performance monitoring and to action to correct detected shortcomings, which is consistent with an operational system dedicated to the provision of user-driven services.



Guiding principles

1.4.2 Principles of involvement

A set of Principles of Involvement have also been formulated to assist nations, agencies and industries to understand the implications of participation in the GOOS. These may be summarised as:

P1. Contributions to the GOOS will be compliant with plans developed and agreed on the basis of the above design principles. A minimum level of prescription is intended but participants need to be assured that their contributions are compatible with those of others and, together, are likely to achieve agreed objectives.

P2. Contributions will be compliant with a defined GOOS data policy.

P3. Contributions should reflect an intent for sustained observations.

P4. Standards of quality will apply to GOOS contributions.

P5. Implementation will be effected using existing national and international systems and organisations where appropriate. The aim is to achieve effective integration of existing entities to serve the needs of the GOOS and thereby achieve multiple use of resources, wherever this is compatible with their existing missions, rather than the creation of new entities.

P6. Implementation will be incremental and progressive, whilst bearing in mind the long term goals. This is intended to give confidence that risks will be controlled and encourages nations and agencies to build on past investments.

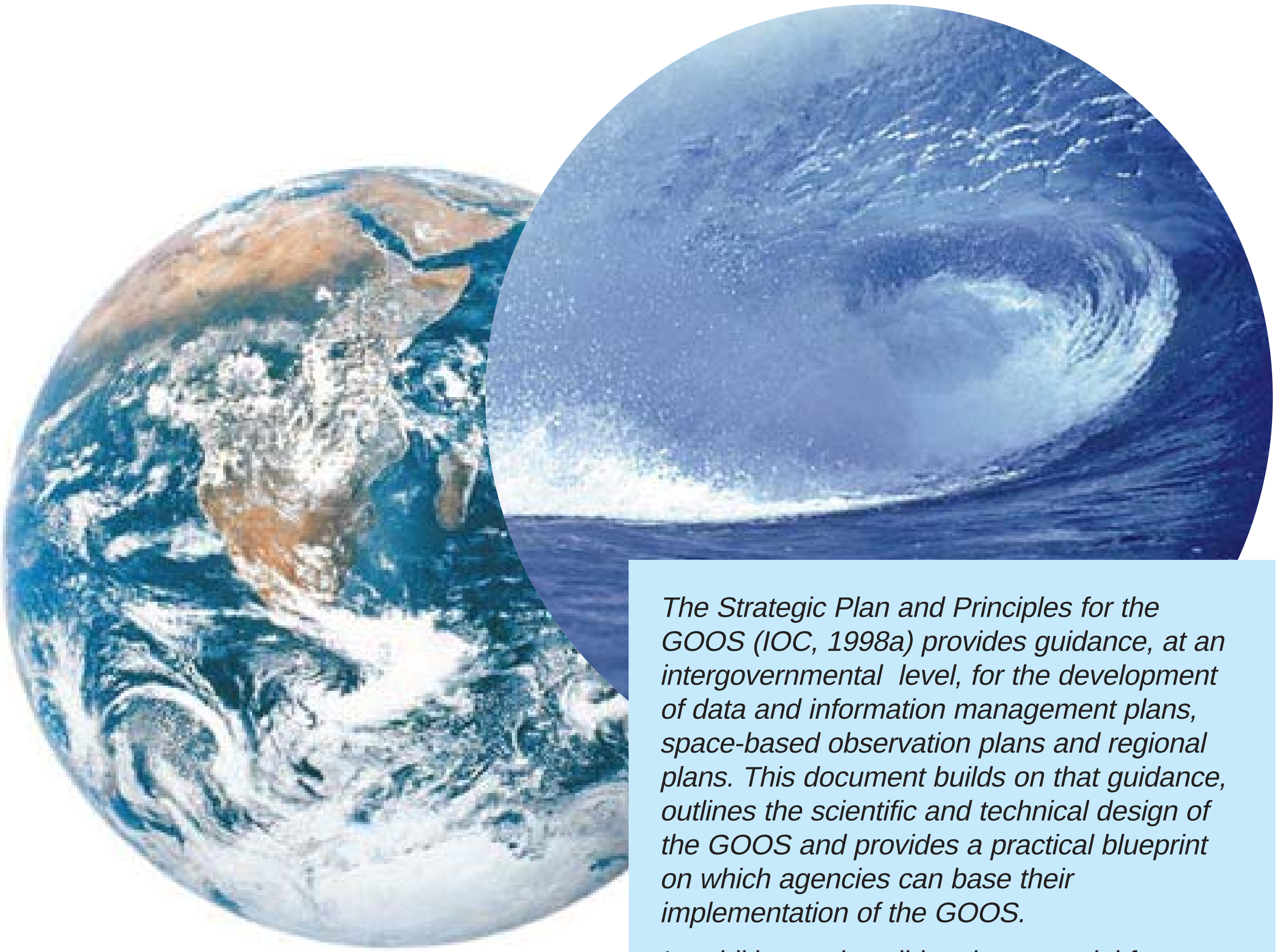
P7. Participation in the GOOS implies an undertaking to help less-developed countries to participate and benefit. Technology transfer to developing countries, an active aid and assistance programme and the exchange of products for basic data will be encouraged.

P8. Participants will have full autonomy in the management of their contributions. This provides assurance that the GOOS has no role in determining how resources will be managed. Its influence will be confined to the encouragement of adherence to plans, principles and practices agreed collectively for the common good.

P9. Contributing nations and organisations will reserve the right to determine and limit their contributions to the GOOS. Although the success of the GOOS depends on long term, sustained observations and their processing to generate agreed products, participants always retain full control of the size and nature of the resources they are willing to commit.

P10.Use of the GOOS 'label' implies conformity with the relevant principles of the GOOS. The GOOS acronym is already in widespread use and, in the absence of overarching GOOS plans and principles, has become associated with a variety of national and international activities. Some of these lack effective association with the intended global system The principle confirms the intention to ensure the quality and dependability of GOOS activities.

2 STRATEGIC GUIDANCE



The Strategic Plan and Principles for the GOOS (IOC, 1998a) provides guidance, at an intergovernmental level, for the development of data and information management plans, space-based observation plans and regional plans. This document builds on that guidance, outlines the scientific and technical design of the GOOS and provides a practical blueprint on which agencies can base their implementation of the GOOS.

In addition to describing the essential features of the GOOS, which are set out in chapter 1, the Strategic Plan recommends, again at an intergovernmental level, methods for establishing the GOOS on a regional basis, proposes a programme for regional and local training and capacity building, calls for pilot projects to be developed to begin the implementation process, defines the needs for technology development to underpin the system, and examines the possibilities for funding the implementation process.

The Strategic Plan has been adopted by the Intergovernmental Committee for the GOOS (I-GOOS) – see annex 1 – and its sponsors; its guidance can be summarised as follows.

2
STRATEGIC GUIDANCE

2.1
Structure and relationships

The GOOS is an intergovernmental enterprise, and is supported as such by national governments. However, each nation will find the most appropriate mechanism for participation in the GOOS and an effective organisational interface with the global system. Regional development is encouraged but at this stage no particular model for such development is advocated.

Both the scientific and the commercial communities may act as contributors to, and elements of, the GOOS. The scientific community has an important role to play because it is science which enables the conversion of ocean observations into useful information. Industry is also a key player, for example in making available platforms for observations, in providing and developing observing technologies, in defining and providing products and services and in releasing data.

2.2
User needs and benefits

To support a new undertaking of the scale and complexity of the GOOS, a clear focus must be placed on what users need. Priorities must be placed upon the data and products derived from them, based on the quantifiable benefits which can be delivered. Estimates of the yield from the GOOS are needed at many scales and are to be derived carefully using standardised methodology and consistent assumptions. Such estimates need to be performed for developing countries. Regional assessments are required where collective economic and political decisions might arise.

The GOOS will provide useful guidance for nations fulfilling their commitments to international Conventions and assessments relating to the state of the oceans and their protection.

2.3
Design guidance

Not all ocean data will be GOOS data. Data will be acceptable if they are consistent with the GOOS data policy and standards, are long-term, systematic and relevant to the overall objectives. The principles set out in section 1.4 are to guide the development of the GOOS. The design of the GOOS must be flexible, expandable and adaptable to changing needs and implementation constraints. Design(s) must also be comprehensible and logical at both a technical and non-technical level, and efficient in the use of resources committed. GOOS product distribution systems will be evaluated before implementation and during operation.

As a basis for organisation and for ease of planning, the GOOS has initially been defined in terms of five 'modules' representing categories of user interest. Module Panels are to represent those interests. Each Panel is to establish the requirements of end-users of marine information that generate demands for services and products. The products in turn define the marine observations necessary for their delivery. The Panel will specify in scientific terms these needs, products and observations as a basis for Implementation Plans or to define tasks requiring further scientific consideration. Panels may also need to consider the design of Pilot or Demonstration Projects that can be used to test the feasibility of GOOS component systems, the generation of products or to facilitate the recruitment of support for the GOOS. The modules are necessarily inter-related and intersecting and will share observations, data networks and facilities, as needed, within one or more integrated system(s).

An integrated strategy is to be devised for the planning of space-based and *in situ* observations. Planning for data and information management is to be carried out jointly with the other Global Observing Systems, (i.e. Global Climate Observing System, and Global Terrestrial Observing System), known collectively as the G3OS, and with existing practitioners in the field.

2.4
Implementation guidance

The GOOS will be implemented in five overlapping phases:

i. planning, including design and technical definition;

ii. operational demonstrations and pilot experiments;

iii. incorporation of suitable existing observing and related activities and new activities that can be implemented now to constitute the Initial GOOS Observing network;

iv. gradual operational implementation of the 'permanent' or ongoing Global Ocean Observing System;

v. continued assessment and improvement in individual aspects and in the entire system.

To the greatest possible degree the GOOS will be built on, and seek to adapt, existing national and international initiatives in the fields of *in situ* and satellite based observing systems, modelling and data assimilation. Implementation plans and detailed specifications of the actions proposed by the Modules should be available in a form and detail from which adaptations and enhancements can be readily defined.

Whilst there is a sound basis on which to build, as demonstrated in chapter 3, there is a need to confirm the value which the GOOS can add, to acquire some specific, new capabilities through pilot and development projects and to improve the coverage of observations in time and space.

Recognising the inevitable sparseness of data in relation to the scales of ocean processes, much of our understanding of ocean behaviour and our ability to forecast events will come from numerical simulation in advanced ocean models nested at different levels from local to global. These models, in both their data assimilation and predictive modes, are themselves a technology in need of development; their power in turn depends on advances in the power of computing systems and mathematical/statistical techniques. It is likely that the expertise will be assembled in a few advanced centres to carry out this development work.

2
STRATEGIC GUIDANCE

In order to encourage national involvement by governmental agencies, non-governmental organisations and the private sector, the implementation strategy will ensure that at the earliest stage they are made fully aware of the benefits that can be gained from the GOOS in general and their participation in particular.

These requirements imply the following planning elements:

a. Benefits of the GOOS organisational framework, GOOS data and GOOS products are documented as quickly as possible in terms suitable for diverse readership and updated frequently;

b. GOOS Plans and other useful documentation are prepared and made available without delay;

c. Strong communication and working arrangements are established among the international GOOS organisation, national corresponding bodies or 'points of contact' and the executives of related international programmes, planning bodies and agencies;

d. A pro-active external communication and 'marketing' strategy for the GOOS is developed.

Much of the implementation may be accomplished using regional alliances, which are strongly encouraged.

Regional projects offer an attractive method for recruiting the participation of smaller countries to achieve 'critical mass', and because they are in a position to reflect local needs and to implement regional training and infrastructure.

The GSC will ensure that the scientific basis of each module and/or element are incorporated into GOOS Implementation Plans. They will be added to and upgraded progressively in step with GOOS development. This document proposes an initial framework and guidance for that process.

2.5 Resources

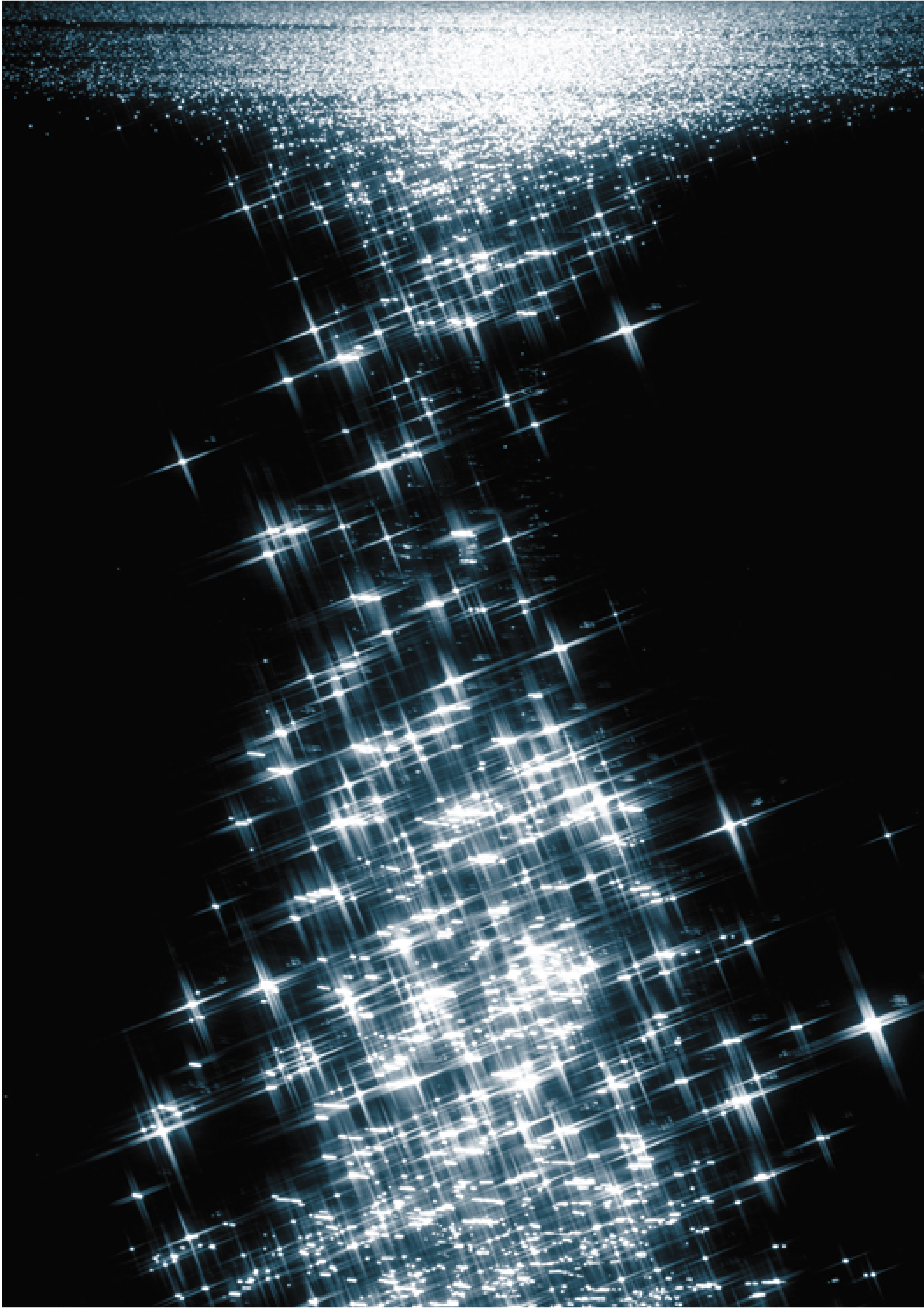
The user community for GOOS products and services will be encouraged to participate in, and to sponsor GOOS design and implementation at the national level. Managers of existing systems will be encouraged to review their activities with a view to the allocation or adaptation of effort to GOOS purposes and hence achieve the benefits of greater efficiency or effectiveness. Such benefits may well arise through national or regional integration. Active efforts will be made to recruit the interest and support of non-governmental corporate sponsors that may benefit from the existence of the GOOS, including selected maritime industries, the World Bank, and the reinsurance industry. Non-governmental environmental organisations may also wish to be involved, especially regarding resource management. In principle, the GOOS can benefit from naval resources committed to monitoring and predicting the behaviour of the oceans and will increase the amount of useful information available to all. Specific action to exploit this synergy is advocated.

In order to assist nations to gain maximum benefit from the GOOS, and to play an effective part in its implementation, it will be necessary to:

a. ensure that technical advice and training is available to equip them to participate in the GOOS and to make effective use of its products;

b. provide assistance, as necessary, to find resources and sponsorship for both training and equipment;

c. encourage dedicated effort, through the main research agencies of the world, to generate GOOS products for use in practical applications, such as coastal modelling and environmental management.



3
THE FOUNDATIONS OF THE GOOS

The aim of this chapter is to demonstrate the nature of the foundations on which the GOOS is being built and the investment already made. Each section describes a different aspect of those foundations and draws out conclusions and the implications for the GOOS.

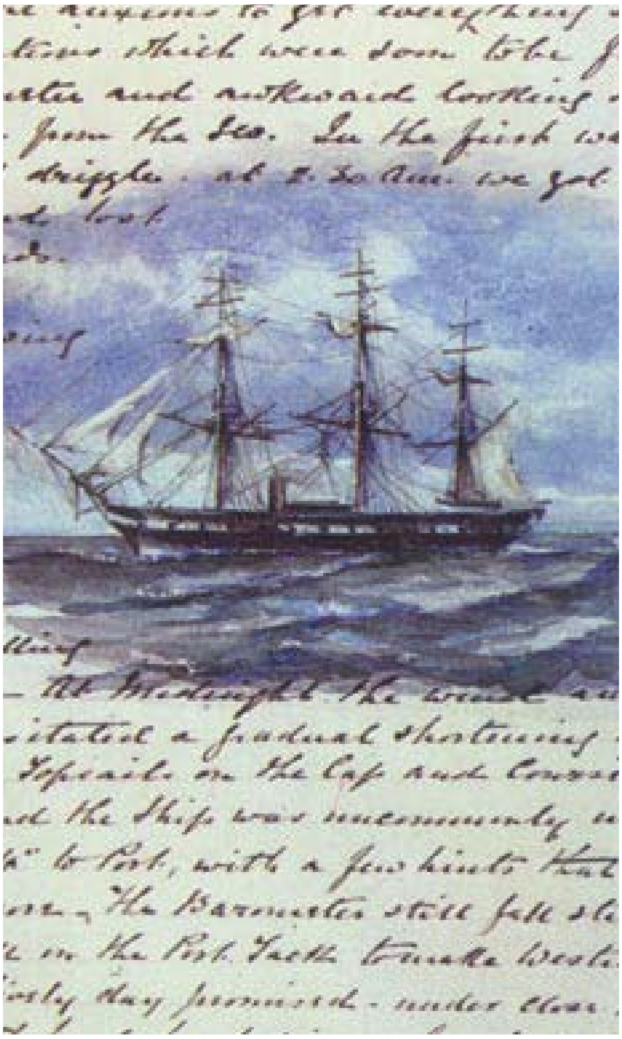
3.1
FOUNDATIONS OF THE GOOS

The legal framework

3.1.1 Antecedents

In 1609, Hugo Grotius published his classic study 'Mare Liberum', which expounded the concept of the freedom of the seas, on the basis that the oceans are a public good, i.e. that which has 'been so constituted by nature that although serving some one person it still suffices for the common use of all other persons'. He argued that this was true in particular for the use of the oceans for navigational purposes. He conceded that 'the sea can be acquired by him who holds the land on both sides', thereby recognising that coastal states would wish to exercise some measure of control beyond the beach, and of some kind of seaward territorial limit. Grotius also opined that it was impossible to exhaust the sea of fish and therefore that they were public goods too.

At least until the mid-nineteenth century writers in the field of international law retained the view that living marine resources were inexhaustible, and perpetuated the concept of a narrow band of coastal sea subject to sovereign control and the open seas beyond, which were 'free for all'. The subsequent evolution of ocean governance, culminating in the 1982 UN Convention on the Law of the Sea, has been well described by Juda (1996).



3.1.2 The 1982 UN Convention on the Law of the Sea

UNCLOS entered into force in November 1994, one year after reaching its 60th ratification accession. The Convention addresses a wide variety of ocean uses and jurisdictional issues.

The legal regime it outlines marks a substantial shift from the view of the oceans, beyond narrow territorial seas, as free and open to all. As described by Juda (loc. cit.) it embodies the culmination of at least five major trends:

1. acceptance of greater national control and jurisdiction over the most significant areas, in terms of human use, of ocean space;
2. recognition of the growing multiplicity of ocean uses and the conflicts of use they may engender;
3. acknowledgement of the need to provide a balanced regime which recognizes the rights of coastal states and those of a larger world community;
4. growing understanding of the need for protection of the physical and ecological environment of the oceans and management of its resources and uses;
5. recognition of the need for international coordination, cooperation and institutions in the governance of ocean space use, paradoxically at a time of acceptance of greater national control of that space.

Thus, Article 3 of the Convention provides for a territorial limit up to 12 nautical miles, measured from baselines defined in the Convention, subject to rights of innocent passage through straits required for international navigation. Responsibilities are also placed on those exercising those rights.

The Convention recognises and elaborates on the Exclusive Economic Zone (EEZ) as a basic juridical zone in ocean law, albeit as a zone *sui generis*, being part neither of the territorial sea nor the high seas, and extending to a maximum distance of 200 nautical miles from the baselines used to measure the territorial sea. In the EEZ coastal states have sovereign rights over 'living and non-living natural resources super adjacent to the sea bed and its sub soil' and limited jurisdictional capacity but not sovereignty.

As to living marine resources, the coastal state has the legal duty to ensure that EEZ resources are protected against over exploitation and to promote their 'optimum utilization'. For which purposes the coastal state is to employ the best available scientific evidence.

Marine scientific activities in the EEZ are made subject to a 'consent regime' which necessitates coastal state approval for research in the EEZ and on the continental shelf. However, researching states and the international organizations have rights too, and consent for scientific research on the shelf is normally not to be withheld except in 'those specific areas which coastal states may at any time publicly designate as areas in which exploitation or detailed exploratory operations' are occurring or will occur 'within a reasonable period of time'.

From the point of view of the GOOS, the most important jurisdictions extend to 'marine scientific research and the protection and preservation of the marine environment'. Part XIII is concerned with marine scientific research in the various ocean spaces; in Part VII such research is explicitly recognised as a freedom to be enjoyed on the high seas. Part XIV is very pertinent in promoting the transfer of marine technology and capacity building by states and international organizations, including the IOC.

All of Part XII of the Convention, comprising some 46 articles, is devoted to the protection of the marine environment. Article 192 stipulates that 'States have the obligation to protect and preserve the marine environment' and to that end are, individually and jointly, regionally and globally, to take appropriate measures 'to prevent reduce and control pollution of the marine environment from any source'. This duty of care extends to the export of pollution damage to the high seas or zones where other states have sovereign rights. There are substantial provisions to deal with vessel-source pollution. The cause of protection is further advanced by legal obligations ranging from the collection of data and scientific study to the preparation of contingency plans and the harmonization of national policies for the protection of the marine environment.

The concepts of 'ecosystems' and 'ecological balance' are specifically alluded to and there is a recognition that whilst legal boundaries are important to states, fish or pollutants are responsive to natural and ecological divisions of ocean space.

3.1.3 The International Convention for the Safety of Life at Sea (SOLAS)

The current Convention was drawn up in 1974, under the auspices of the IMO.

It makes two particular provisions of relevance to the GOOS, relating to the collection and dissemination of meteorological data, and services based upon them, as an aid to navigation.

- Regulation 2 requires the master of every ship to communicate by all means at his disposal, information relating to contact with dangerous, unexpected phenomena such as tropical storms, ice or severe icing conditions and other storms for which no warning has been given.

- Regulation 4 requires governments to encourage the collection of data by ships at sea and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation. They are also to co-operate in the provision of specific meteorological services and to arrange for selected ships to be equipped to make relevant observations.

The Voluntary Observing Ship programme of WMO (3.6.3) is sustained in part on the basis of these regulations.

3.1
FOUNDATIONS OF THE GOOS

The legal framework

3.1.4 The Framework Convention on Climate Change

Over 150 States signed the United Nations Framework Convention on Climate Change in June 1992 at the Rio ‘Earth Summit’. In doing so they recognised climate change as ‘a common concern of humankind’. Their goal was to forge a global strategy ‘to protect the climate system for present and future generations’. Governments that become Parties to the Convention seek to achieve its ultimate objective of stabilising ‘greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system – within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner’.

The Convention emphasises that developed countries are mainly responsible for historic and current emissions and must take the lead in combating climate change.

By becoming Parties to the Convention, both developed and developing countries accept a number of commitments. These include:

- Article 4.1(a) – Submitting for review information about the quantities of greenhouse gases that they emit, by source, and about their national sinks.
- Article 4.1(b) – Carrying out national programmes for mitigating climate change and adapting to its effects.
- Article 4.1(g) – Promoting and co-operating in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system.
- Article 4.1(h) – Promoting and co-operating in the full, open and prompt exchange of relevant information.
- Article 4.1(i) – Promoting education programmes and public awareness about climate change and its likely effects.

Developed countries accept a number of additional commitments specific only to them. Some of the most important are:

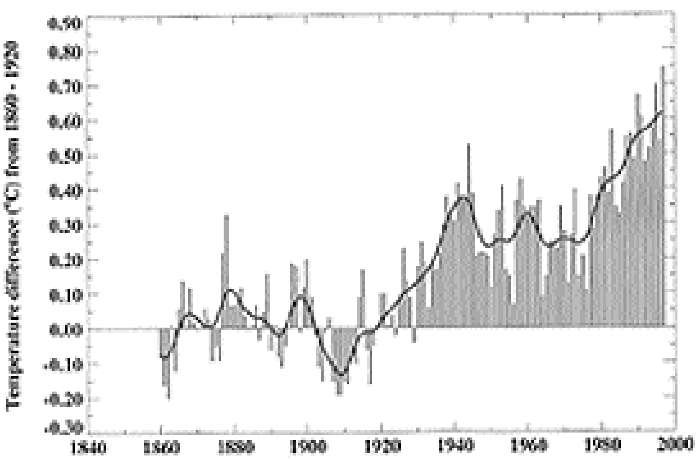
- Article 4.2 – Demonstrate that they are taking the lead in achieving the objective of the Convention, by adopting policies designed to limit their greenhouse gas emissions and to protect and enhance their greenhouse gas sinks and reservoirs. They will also submit detailed information on their progress. The Conference of the Parties will review the overall implementation and adequacy of this commitment at least twice during the 1990s.
- Article 4.3 – Transferring to developing countries financial and technological resources above and beyond what is already available through existing development assistance, and supporting efforts by these countries to fulfil their commitments under the Convention.
- Article 4.8 – Helping developing countries that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

Article 5 elaborates Article 4.1(g) by requiring that in carrying out their commitments ‘the Parties shall:

a. Support and further develop, as appropriate, international and intergovernmental programmes and networks or organizations aimed at defining, conducting, assessing and financing research, data collection and systematic observation, taking into account the need to minimise duplication of effort;

b Support international and intergovernmental efforts to strengthen systematic observation and national scientific and technical research capacities and capabilities, particularly in developing countries, and to promote access to, and the exchange of, data and analyses thereof obtained from areas beyond national jurisdiction; and

c Take into account the particular concerns and needs of developing countries and co-operate in improving their endogenous capacities and capabilities to participate in the efforts referred to in subpargraphs (a) and (b) above’.



Combined global land air and sea surface temperatures 1860-1997 (relative to 1860-1920 average)

3.1.5 The Convention on Biodiversity

This Convention was also adopted in Rio Janeiro in June 1992. Its objectives "are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources".

In Article 7 Contracting Parties commit, as far as possible and as appropriate, and within their limits of jurisdiction, to identify and monitor:

- components of biological diversity important for their conservation and sustainable use;
- processes that have or are likely to have significant adverse impacts on such conservation and use.

Article 8 requires that processes be regulated or managed where a significant adverse effect is determined.

Article 5 encourages international cooperation in respect of areas beyond national jurisdiction, and Article 6 requires the integration of the conservation and sustainable use of biological diversity into "relevant sectoral or cross-sectoral plans, programmes and policies".

Article 12 requires Contracting Parties to establish and maintain programmes for scientific and technical education and training, and to promote relevant research, taking into account the special needs of developing countries. A Subsidiary Body on Scientific, Technical and Technological Advice was set up to aid the Contracting Parties in these fields.

Article 17 commits the Contracting Parties to facilitate the exchange of information from all publicly available sources.

3.1.6 Agenda 21, the Programme of Action for Sustainable Development

This Programme was also adopted by the UNCED in Rio de Janeiro, June 1992. Chapter 17 of the Agenda is devoted to protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources. It outlines seven programme areas:

- integrated management and sustainable development of coastal and marine areas, including EEZs;
- marine environmental protection;
- sustainable use and conservation of marine living resources of the high seas;
- sustainable use and conservation of marine living resources under national jurisdiction;
- addressing critical uncertainties for the management of the marine environment and climate change;
- strengthening international, including regional, cooperation and coordination;
- sustainable development of small islands;

and defines for each of them the basis for action, objectives to be achieved, activities to be carried out and means of implementation.

Specific reference to the GOOS, as an important activity contributing to the achievement of the goals of the Programme, is made in Chapter 17, Programme Area A, paragraphs 106, 107(b) and 114. Furthermore, the modular approach taken in planning the GOOS (see chapter 4.5 of this document) is reflected in the requirements of the different sections of Agenda 21. For instance, section 8 applies to the Coastal Module of GOOS (4.5.5) in requiring coastal states to improve their capacity to collect, analyse, assess and use information for sustainable use of resources, including environmental impacts of activities affecting the coastal and marine areas. Section 9 demands strengthening of cooperation with developing countries to achieve this, and section 14

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calls for international cooperation between states in making the appropriate observations and developing the appropriate information management systems. Section 36 applies to the Health of the Oceans (HOTO) Module of GOOS (4.5.3), in calling on states to make systematic observations on the state of health of the marine environment. Sections 61, 70 and 91 apply to the Living Marine Resources Module of GOOS (4.5.4) in asking states to collect and exchange information about the conservation and sustainable use of marine living resources on the high seas and in coastal seas. Sections 104 and 105 call for carrying out research and making and exchanging observations to improve understanding of the role of the ocean in global processes such as climate change, relevant to the Climate Module of GOOS (4.5.2). Improved forecasts of marine conditions are an expected outcome.

3.1.7 The Agreement for the Implementation of the Provisions of the UNCLOS relating to the Conservation of Straddling Fish Stocks and Highly Migratory Fish Stocks

This Agreement, reached in 1995, originated in the Rio Declaration and Chapter 17 of Agenda 21, which require States to take effective action to ensure that high seas fisheries are managed in accordance with the UNCLOS. It recognises that the current management of such fisheries is inadequate in many areas, that some resources are overutilized and that there are a number of specific problems, including those of unreliable databases and a lack of sufficient cooperation between States.

A*rticle 5 of the Agreement sets out some general principles, which include requirements:*

- that measures adopted to ensure long-term sustainability are ‘based on the best scientific evidence available’, and ‘qualified by relevant environmental and economic factors’.
- to collect and share, in a timely manner, complete and accurate data, the requirements for which are set out in Annex 1 to the Agreement, but include data relating to fisheries activities as well as information from national and international research programmes, that are to be promoted.
- to implement and enforce conservation and management measures through effective monitoring, control and surveillance.

Article 8 requires that Coastal States and States fishing on the high seas shall pursue cooperation ‘either directly or through appropriate sub-regional or regional fisheries management organizations or arrangements’. The functions of States and such management organizations and arrangements are elaborated in Articles 9 and 10.

Article 14 specifies the responsibilities of States in collecting and providing information and in conducting scientific research. Articles 24-26 define the special requirements of developing States in relation to conservation and management of straddling fish stocks and highly migratory fish stocks.

3.1.8 The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

This Convention, commonly known as **The London Convention 1972**, provides the international regime for the disposal of wastes at sea from ships, platforms and aircraft. The Convention specifies a "black" list, that comprises substances and materials prohibited from dumping at sea, and a "grey" list that specifies substances requiring "special care". Since 1972, the black and grey lists have been amended such that, for example, dumping of radioactive matter and industrial wastes are now prohibited (with some exceptions in cases where individual Contracting Parties have expressed reservations about specific amendments). In I996, the Convention adopted a new Protocol that is based on a so-called "reverse listing" approach similar to that used in the renegotiated Oslo and Paris Conventions known as the OSPAR Convention – see paragraph 3.1.11. The reverse list specifies wastes for which disposal in the sea can be considered.

The London Convention requires Contracting Parties to monitor the seas, to undertake evaluations relating to sea dumping activities and to conduct research. These responsibilities could be carried out and demonstrated through the GOOS.

3.1.9 The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities

This programme (GPA/LBA) was adopted by an Intergovernmental Conference, meeting under the auspices of UNEP, in Washington DC during Oct-Nov 1995. Its aims are to prevent the degradation of the marine environment from land-based activities, by helping States to preserve and protect the marine environment. It is designed to assist States in taking actions individually or jointly, that will lead to the prevention, reduction, control and/or elimination of such degradation. It is envisaged that the GPA will contribute to maintaining and, where appropriate, restoring the productive capacity and biodiversity of the marine environment, ensuring the protection of human health and promoting the conservation and sustainable use of living marine resources.

The GPA/LBA is a source of conceptual and practical guidance designed to achieve effective, integrated coastal area management. Such management is impossible without biological, chemical and physical data, many of which have to be captured routinely in the marine environment, and are therefore within the province of the GOOS. Such data are required:

- initially, simply to design goal-oriented monitoring programmes;
- to enable research into the transport and evolution of pollutants in the marine environment, and into its assimilative capacity ;
- in the design of specific programmes of prevention and amelioration;
- to monitor progress against management objectives.

The GPA/LBA proposes specific objectives and corresponding national, regional and international actions in respect of: persistent organic pollutants, litter, heavy metals, oils, sediment mobilisation, nutrients, radioactive substances, sewage and physical alteration and destruction of habitats.

The next step is the construction of action plans based on regional evaluations of the damage and threats posed by land-based activities.

The legal framework

3.1.10 Convention on the Protection of the Marine Environment of the Baltic Sea Area

The first Convention on the Protection of the Marine Environment of the Baltic Sea Area, the Helsinki Convention, was signed in 1974 by a number of coastal states. It was issued to protect the marine environment of that Sea and was the first international agreement to cover all sources of pollution - airborne, from land and from ships. In 1992, a new Convention was signed by all the countries bordering on the Baltic Sea and by the European Economic Community.

The governing body of the Convention is the Helsinki Commission - also known as HELCOM. The Commission meets annually and, from time to time, meetings are held at ministerial level. Decisions taken by the Helsinki Commission – which are reached unanimously – are regarded as recommendations to the governments concerned, for incorporation into national legislation. Regular, comprehensive assessments of the state of the Baltic Sea are published. The most recent was for the period 1989-93.

3.1.11 The Oslo and Paris Conventions, and OSPAR

The Oslo and Paris Conventions are the regulatory agreements for the prevention of pollution in the maritime area of the North East Atlantic arising respectively from disposal from ships and aircraft and discharges from land (including atmospheric emissions). The maritime area is defined as the area seaward of nationally designated baselines. The Conventions were renegotiated and combined into a single Convention, known as the OSPAR Convention, in 1992. Implementation of the Convention is by a Commission of the Contracting Parties.
An Assessment and Monitoring Committee (ASMO) collects and makes available scientific information on the status of Convention waters.

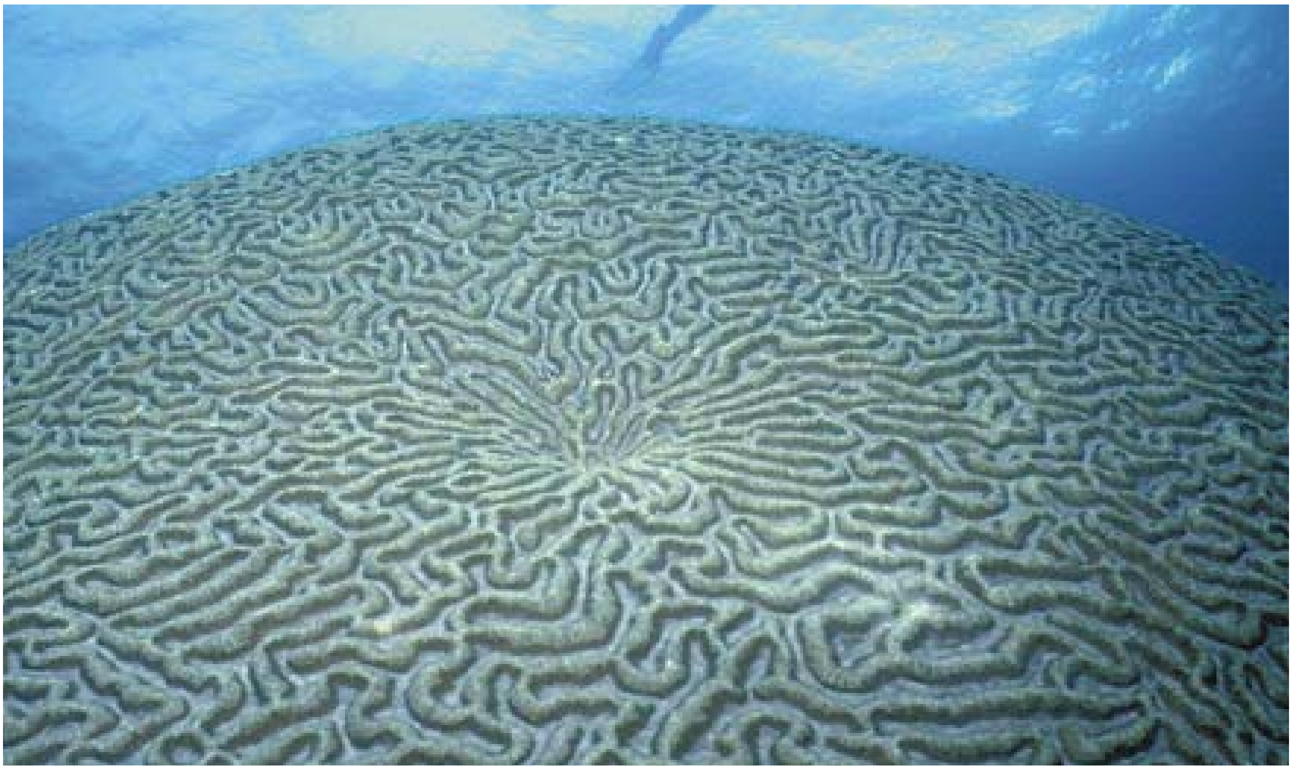
3.1.12 Other Conventions

UNEP provides the secretariat or administers several global agreements relevant to the protection of the marine environment:

- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) promotes the sustainability of trade in wildlife while offering the protection to species that are threatened or endangered due to over-exploitation, habitat destruction and pollution. As far as the marine environment is concerned, whales, turtles and some coral species are in the focus of CITES.

- Convention for the Conservation of Migratory Species lays the ground rules for the protection of migratory species, including marine birds.

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their disposal regulates, amongst others, the maritime transport and disposal of hazardous waste.



3.1.13 Conclusions and implications for the GOOS

UNCLOS provides the legal basis for action in implementing the GOOS by defining the juridical zones in the form of territorial seas, the EEZ and the high seas, and the rights and obligations of States within those zones. Arguably, the GOOS could not have been implemented successfully as a co-operative venture without the clarification of these matters that the UNCLOS provides. Furthermore, the Law recognises and deals with the conflicts of the multiple and growing uses of the oceans and the need for protection of the environment; two strong drivers of the GOOS.

The SOLAS is important for the GOOS because it encourages the collection and dissemination of environmental data at sea and their distribution in real-time. SOLAS also recognises that there are important information services, bearing on efficient navigation and safety, that are enabled by that collection and its subsequent processing. The SOOP of the IGOSS and the VOS scheme of WMO benefit from that encouragement.

The Conventions on Climate Change and Biodiversity, the Agenda 21 Programme and the Agreement on 'Straddling Stocks' are seminal because they call for sustainable use of different components of the environment, and require Contracting Parties to monitor those components, to detect adverse effects, to verify the effectiveness of their mitigation policies, and enable forecasts over a range of timescales. The GOOS is the obvious programme to carry out these tasks at the global scale. It may also be an appropriate vehicle for monitoring ocean disposal of carbon dioxide, should that become accepted practice as part of controlling greenhouse gas emissions. ***Nations that commit to the Conventions and Agenda 21 Programme are in effect committing to relevant parts of the GOOS.***

By committing the Parties to fulfil their responsibilities in specific ways, that are highly relevant to the GOOS and totally compatible with its principles, the Conventions and Programme have a deeper significance. Thus all the agreements look to the scientific method to determine what should be controlled and how, what should be monitored and to help interpret the results; all establish specific responsibilities and rights of nations; all look to developed countries to bear the major share of the burden and to diffuse awareness and technology; all extol the advantages of cooperation and global or regional solidarity; all seek the maximum possible transparency and exchange of data to achieve it.

Specifically, the Climate Module of the GOOS elaborates the commitments of the Parties to the FCCC that arise from Articles 4.1(g) and 5 in respect of the oceans, covering such matters as data collection, systematic observation, the need to minimise the duplication of effort, support for international and intergovernmental efforts and capacity and capability building.

Agenda 21, Chapter 17 makes specific reference to the GOOS. It provides the highest-level, relevant agreement that exists between governments, intergovernmental, and non-governmental organizations, through which a comprehensive long-term programme for sustainable development of the environment has been defined and the seeds for its implementation sown. It has given fresh impetus to some existing and new conventions and agreements dealing with particular sectoral issues. Thus the GPA/LBA elaborates what needs to be done globally in respect of pollution originating on land whilst the London Convention does so in respect of dumping at sea. Both require monitoring of the kind that the GOOS can provide.

The regional Conventions of HELCOM and OSPAR demonstrate the effectiveness of focused regional activities. In dealing with problems on the high seas, the Agreement on 'Straddling Stocks' extols the virtues of regional cooperation.

Notwithstanding the benefits to be had from environmental data, information about national practices and the state of the environment can be politically sensitive so, in practice, there is a need to build confidence that data will not be misused. An incremental approach is indicated.

3.2
FOUNDATIONS OF THE GOOS

The institutional framework

3.2.1 The sponsors and the related Global Observing Systems

The GOOS is cosponsored by three United Nations bodies, the IOC of the UNESCO, the WMO and the UNEP and by the non-governmental organization, ICSU. Annex 1 outlines the particular interests and locus of these and other intergovernmental and non-governmental players in the protection and efficient, safe and sustainable use of the marine environment. The GOOS Project Office is based with the IOC Secretariat.

The GCOS is co-sponsored by the same organizations, while the GTOS is co-sponsored by the FAO, ICSU, UNESCO, UNEP and WMO. Collectively the global ocean, terrestrial and climate observing systems are known as the G3OS. They are complementary, mutually supportive and have a common focus in the requirements of Agenda 21. The WWW of WMO also incorporates a global observing system, whose primary purpose is to sustain operational meteorological and allied services. The GCOS Joint Planning Office is based with the WMO Secretariat, and the FAO is the host agency for the GTOS Secretariat.

The climate module of the GOOS is the ocean component of the GCOS, which makes for an integral relationship between the two observing systems. Their joint work in this area is carried out through the Ocean Observations Panel for Climate, that they jointly sponsor with the World Climate Research Programme (WCRP).

The GOOS and the GTOS have a common interest in the coastal zone and systems will be designed and implemented cooperatively in this region.

The sponsors, acting collectively, are in a strong position to ensure that the development of the Global Observing Systems (G3OS) is guided by a common, integrated strategy. Integration, collaboration and simplification of the systems has begun at several levels. At the conceptual level, system objectives and strategies are harmonised. At the technical level, the secretariats are working closely together, and working groups are being rationalised within and between programmes on functional issues such as space-based observations, *in situ* observations, data management and telecommunications (see annex 2). A Sponsors Group has been formed to operate at the political level of the sponsors and governments.

3.2.2 An Integrated Global Observing Strategy

The Committee on Earth Observation Satellites (CEOS) and the International Group of Funding Agencies for global change research (IGFA) have similarly seen the need for an Integrated Global Observing Strategy (IGOS) as a joint product of all agencies involved in the collection and analysis of both space-based and *in situ* data. CEOS/IGFA have established a Strategic Implementation Team for the purpose of developing such a strategy.

The strategy will respond to three principal needs:

a. to establish a clear set of transnational requirements, to help to minimise unnecessary duplication of observations and assist in the improved allocation of resources between different types of observation systems

b. to recognize the interdependence of measurements for meeting all data requirements, *in situ* and space-based, across all countries and data types, and the roles of rapid data transmission, data assimilation and modelling in bringing about the necessary synthesis. Since modelling and *in situ* data are not the remit of CEOS, partnerships are required. This will:

- ease the creation of improved higher level products by facilitating the integration of multiple data sets from different agencies and national and international organisations;
- provide a framework for decisions on continuity and spatial comprehensiveness of key observations;
- identify situations where existing international arrangements do not exist for the management and distribution of key global observations and products,
- assist the migration of systems from research to operational status.

c. to take into account the way governments respond to requests for funding. There is a need for an overarching view of need, current system capabilities and limitations.

Both the G3OS and the CEOS/IGFA Strategic Implementation Team have decided to proceed with pilot or prototype projects to demonstrate the utility of integrated global observations and to work out, at a reasonable scale, the practical difficulties in putting such systems into operation. Those of particular relevance to GOOS are the Global Ocean Data Assimilation Experiment (6.7) and a long-term ocean biology measurement project. The success of the demonstration activities is expected to help to leverage broader support for global observation activities.

3.2.3 Conclusions and implications for the GOOS

The GOOS clearly benefits considerably from having sponsors that individually and collectively bring distinct, useful insights and experience to bear, and are used to working together. The UN agencies provide access to governments of developing and developed countries, and have comprehensive regional networks. IOC's programmes are uniquely focused on the oceans; the WMO has extensive experience in the enabling and provision of operational services in the sister discipline of meteorology. UNEP has a wide remit covering all aspects of the environment and administers many of the sectoral and regional conventions that the GOOS serves. ICSU, as a non-governmental agency, has an additional, complementary constituency and provides direct access to the scientific community.

The Global Observing Systems are interrelated and provide the foci that a single GOS would have to create if it was to be successful. The IGOS initiative of CEOS/IGFA is helpful
in demonstrating the willingness of the managers of important resources to meet the needs of users and welcome in recognising that the combination of remotely sensed and *in situ* data is potentially more powerful than either alone. They clearly support the thesis that assimilation into models provides a potent strategy to realise that potential.

The sponsoring arrangements that support GOOS, as one element of the Global Observing Systems (G3OS), ensure that its planning at the international level is well informed. Efforts to create and implement an Integrated Global Observing Strategy are responding to real needs at this level and hold out the promise of an improved investment of resources. However, the links being formed between GOOS, GCOS, and GTOS at the level of the sponsors have not yet percolated down to the national level, and it is important that this deficiency be addressed.

3.3
FOUNDATIONS OF THE GOOS

The economic base

3.3.1 Introduction

The primary economic rationale for operational oceanography, and hence the GOOS, derives from the more efficient use of resources that it enables. That efficiency manifests itself in strategic and tactical decisions that minimise the consumption of resources and achieve a maximum possible useful output in the prevailing circumstances. The strategic decisions concern such long term issues as the choice of crop and other forms of investment, and the design of structures, equipment and procedures. The tactical decisions relate to the short term deployment or management of the assets created by those strategic decisions. Resource minimisation includes cost reduction and the avoidance of loss of life and property – including degradation of the environment itself.

It is certainly possible to appropriate some such information and gain sufficient competitive advantage from it to justify the cost of its capture or creation – as in the collection and use of wave and current data to enable the optimum design of an offshore structure for use at a specific site, for example. However, it is the nature of the environment and the value-adding process described in chapter 4 that basic data often have multiple uses and maximum value is to be had from the resulting information if it is treated as a public good – and therefore, by definition, not possessed by any one sectional interest.

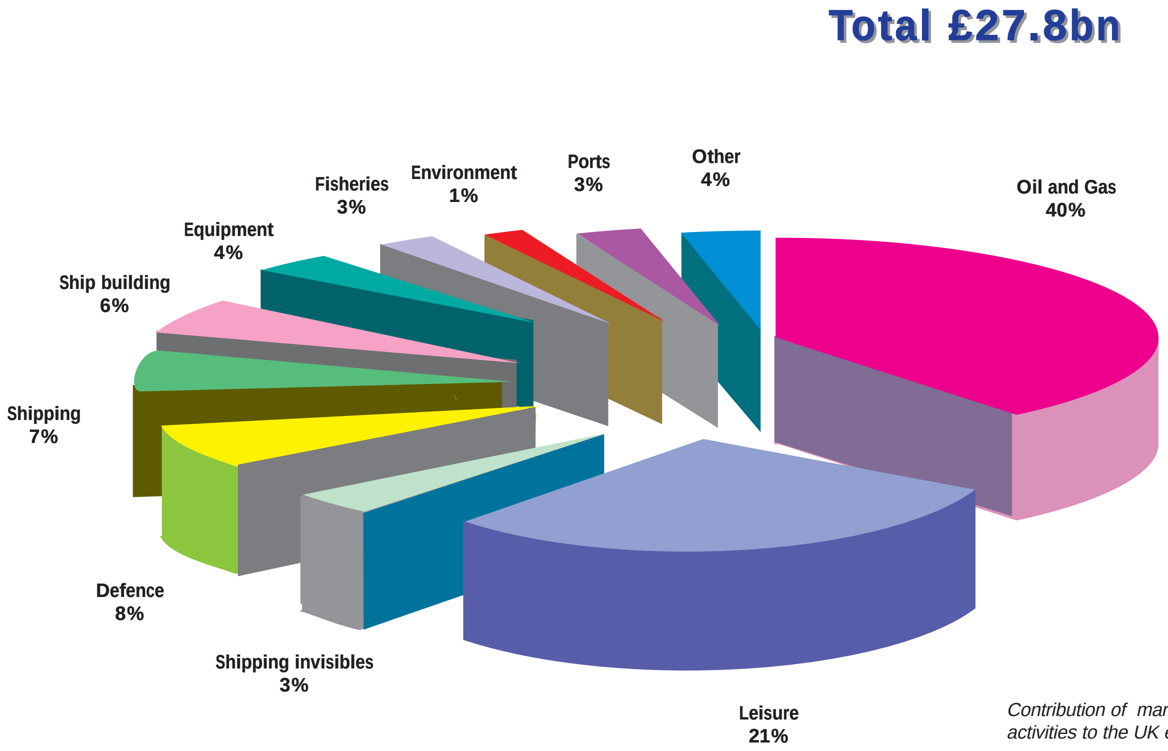
These considerations have considerable significance for the economic assessment of the GOOS. Thus:

a. It is impossible to identify and enumerate all the beneficiaries of the resulting information services, because there are so many.

b. Practical assessments of economic benefit have to be made at the industry or sector level. This has the advantage that the problem of 'winners and losers', that inevitably result from the general adoption of more efficient practices within a competitive industry, can be side-stepped. Such assessments also benefit from the general availability of economic data at this level. However such simplification is at the expense of precision in quantifying the actual benefits that may be realised.

c. As a consequence of this and other inherent characteristics of large scale, long term endeavours such as the GOOS, it is difficult to employ the tools of cost/benefit analysis (CBA), that are designed for use at the level of a specific project or programme, with specific inputs and outputs (Brown, 1995). Notwithstanding these difficulties CBA could play a useful partial role as discussed below.

d. The absence of benefits that can be appropriated does not preclude the use of private sector funding for information services, as witnessed by the obvious viability of the news media as providers of public goods in the form of information about and analyses of current events. However, their funding has to be through a cross subsidy of some kind, e.g. from advertising or taxation in the form of licence fees. The important point is that the market price of such public good services provides little or no guidance as to their value in influencing social and economic decisions.



Contribution of marine-related activities to the UK economy

In the case of the GOOS, two approaches have been adopted to deal with these difficulties, and yet produce a credible economic case. These may be characterised as:

- the analogue or scaling approach
  – that is based on the hypothesis that data from a particular event or economic sector can be scaled up to obtain estimates of global costs and benefits. The method demands the availability of economic data that have been gathered on a consistent basis. At best, the approach provides 'broad brush' estimates
- *ex post* CBA
  – provides a more formal analysis, carried out after the event, that delivers the present economic value of a series of costs and benefits incurred during a specific project over a period of time. This approach overcomes many of the difficulties for *ex ante* CBA identified by Brown (1995) but it's predictive value is obviously limited, except in building up a track record of 'sound judgements' and by providing useful insights that can help to sharpen the scaling approach and subsequent *ex ante* CBA.

Recently, Costanza *et al* (1997) have employed a new approach to value the services that ecological systems perform in sustaining the Earth's life support system. The incremental value added per annum of such services is estimated to be between 1 and 3 times the global GNP valued by conventional economic methods, so if adopted generally the implications for almost all decisions about the use of natural resources would be profound. That issue is not addressed here but the paper is instructive in:

- cataloguing the range of non-market goods and services that the marine environment in particular provides in support to other industries, including gas and climate regulation, waste treatment, food production and recreation, and
- suggesting values for these.

It is suggested that the value of the marine environment as a whole obtained in this way is some $21 trillion per annum of which $8.5 trillion is 'obtained' from the open oceans and $12.5 trillion from coastal/shelf zones. The terrestrial environment as a whole is valued at $33 trillion per annum. Although the numerical values are open to debate, the study does demonstrate that the non-market goods and services provided by ecosystems make an important contribution to human welfare. The global marine ecosystem has an intrinsic value regardless of its computed economic value, but this approach attempts to assess every concievable aspect of value which would be converted into monetary value. In general terms, their neglect places too great a net value on activities that reduce or destroy the ability of ecosystems to provide the services currently taken for granted.

This approach is not sufficiently mature to be taken into an economic assessment of the kind being discussed here but, qualitatively, the inclusion of such a valuation can only enhance the case for a GOOS that will place ecosystem management on a more numerate footing.

3.3.2 The scaling approach

Benefits

Flemming (1994) and in OECD (1994) has developed the economic case for the GOOS on the basis of postulated improvements in overall efficiency of the marine value-adding sector that the GOOS may enable. His conclusions are based on:

- Pontecorvo *et al* (1980) who set out the principles used by the U.S. National Income Accounting system to establish the proportion of GNP that was attributable to marine industries and services. That analysis was repeated in 1989, Pontecorvo (1989), and produced an estimate that 2.6% of U.S. GNP, or approximately $109 billion per annum was attributable to this sector in 1987.
- Franklin (1989) who carried out a similar analysis in Australia and arrived at a total for the sector of $9 billion per annum, or 3.9% of Australian GNP.
- Pugh and Skinner (1996) who estimated that marine related activities contributed £27.8 billion, or 4.8% of GDP, to the UK economy in 1994-95.

  He then goes on to suggest that these fractions of GNP are representative of the major economies and that the global marine sector represents an economic activity of some $800 billion - $1000 billion per annum. On this basis each 1% of efficiency gain in the marine sector will deliver $8 billion to $10 billion per annum of benefits. It is important to note in passing that the benefits may not fall to the sector, but to the consumers of its services and products, and that there may well be losers both within the sector and among its suppliers. The key point is that the GOOS environmental information services enable the marine sector to deliver more useful output from less input.

Brown (1996) has criticised the assumption of time invariance of costs and benefits obtained in this way. He points to the inevitable start-up period before the GOOS services are fully used, the long time period of supposed use (10 - 20 years) and challenges the implicit assumption in the calculations that the 'marine sector' will in future contribute the same sort of GNP as in these historic 'snapshot' calculations.

The approach is conservative in that it focuses on the marine sector alone. As in the case of meteorology, it is clear that some of the benefits of information about the expected behaviour of the atmosphere or ocean, accrue outside the domain that is monitored and predicted; a point that is further demonstrated below.

However, the approach is heroic in postulating the scale of possible efficiency gains. To the extent that oceanographic information services are similar to meteorological services,

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it is possible to shed some further light on the matter. Thus, Teske and Robinson (1994) have suggested that the Meteorological Office services deliver benefits of some £0.5 billion – £1.0 billion per annum to the UK economy. This represents a $^1/_4$ to $^1/_2$ % improvement in the efficiency of that economy averaged over all sectors, many of which are obviously not weather dependent. A 1% improvement in efficiency of the marine sector as a result of GOOS would produce benefits for the UK of £0.3 billion, a figure that is credible by comparison. Nevertheless, it is clear that benefit estimates obtained by this method are likely to be correct to within a factor of 2 at best.

Costs

The cost of developing the GOOS has not yet been calculated accurately, but some broad estimates were made by the OECD: Megascience Forum (OECD, 1994) from which the following has been extracted.

> *"The expenditure on WOCE has been about $100 million a year for ten years to cover the costs of ships and* in situ *data gathering, excluding satellite costs. The collection and transmission of IGOSS, GLOSS and DRIBU data cost about $60 million per year. The cost of operational meteorology is of the order of $2 billion per year, including meteorological satellites, ground-based stations, marine observations, and forecasting centres. Papers presented at the GOOS Workshop in September 1990 and at the international Group of Funding Agencies for Global Change Research (IGFA) meeting in 1991 suggested, using a broad analogy, that GOOS would cost about as much as a fully implemented meteorological system. A Japanese government paper presented to the IOC Panel on "The Case for GOOS" (IOC/INF-915) in 1992 estimated that the cost of operating a fully developed GOOS, excluding satellites, after the year 2000 would be $2 billion per year for all activities by all countries in GOOS. IOC/INF-915 estimated that the overall cost of implementing GOOS would be of the order of $2 billion per year but that about half of that represented the cost of some satellite missions, ship operations, and other deployments of instruments at sea, that are likely to take place anyway for other, less coordinated reasons. Thus, investment in GOOS contributes added value to existing systems or to systems that will exist in five to ten years even without GOOS.*
>
> *The applications of the different technologies in GOOS drifting buoys, subsurface floats, moorings, autonomous vehicles, tomography, etc. – are each likely to incur costs of the order of $100 million per year. Global data telecommunications, data management, and modelling centres will add a further cost of the order of $100 million per year. The full implementation of GOOS will probably require some dedicated ocean remote sensing missions, further adding to the cost".*

The report of the OECD Megascience Forum did not commit itself to any best estimate of the real cost of the GOOS on the basis of these very rough figures, but an additional cost of operation of the order of $1 billion to $2 billion per year was provisionally accepted as reasonable and was endorsed as such by the Forum.

For comparison, the combined global expenditure at present on marine science and technology research and development, civil and military, including expenditure by governments and industry is of the order of $5 billion to $10 billion per year (IOC, 1993).

It is clear that a consistent basis of estimating and recording the full costs of operational oceanography enabled by GOOS is required. Satellite costs are an important component and should certainly be included. Full cost estimates need to include the costs of generating and delivering basic and derived products and the costs of

applying the information by the user. The way in which costs are recovered will also affect how services are provided and possibly the overall benefit/cost ratios.

Ryder (1996) has suggested, by analogy with operational meteorology, that an operational oceanography centre providing a nation or region with basic products based on information from the GOOS and allied data might expect to spend a half of its budget on making observations and archiving the results but would import similar data having a value at least an order of magnitude greater than this – demonstrating the significance of free exchange of such data. Research in support of operations might consume 15-20% of the budget with 30-35% being taken up by the cost of telecommunications and data processing, particularly in the form of numerical modelling. In meteorology, tailoring and interpreting basic products to increase their value for end-users can be as costly as the generation of basic products. There is no reason to suppose that products based on the GOOS data will be radically different.

Ryder (ibid.) also notes that governments in western Europe and in the US are prepared to invest some 0.01% to 0.02% of GNP in the infrastructure of their National Meteorological Services. This broadly confirms the estimate of the investment in global meteorology of $1 billion – $2 billion, and reinforces the proposition that scaling according to GNP is realistic across quite a wide range of economies.

Benefit/cost ratio

The above indicates that the benefits of the GOOS are likely to exceed, by a comfortable margin, the costs of creating and distributing the services that will deliver them. The most optimistic figures suggest a ratio in excess of 10:1, the most pessimistic 4:1, with a warning that all estimates may be in error by a factor of two.

Such an analysis does not provide the basis for a complete, comprehensive programme of investment in the GOOS spanning some 10-15 years, but suggests that the vision is well founded and that informed, phased investment on specific elements of the end-to-end system offers a sensible strategy, particularly where key steps can tested experimentally and evaluated on the basis of conventional cost benefit analysis.

3.3.3 Cost benefit analysis

Sassone and Weiher (1996) have carried out a highly relevant, ex post cost benefit analysis of TOGA and its implications for operational prediction of ENSO (see 6.2). The study can be criticised for not including all the ongoing and sunk costs borne by the U.S. and other economies of producing/distributing/using seasonal forecasts and their effects on potential uptake of ENSO forecasts, and for ignoring the effects of ENSO outside the U.S. - on market prices, for example. However these do not obviously negate the results or method.

The benefits considered are those available to U.S. agriculture as a result of improved seasonal to interannual weather forecasts based on the forecast system – knowledge, observing systems and modelling tools – largely created by the TOGA research programme.
The benefits arise because farmers who know in advance whether the coming growing season will be warmer or cooler than average, or wetter or drier, can adjust their planting strategy accordingly and achieve a more successful harvest than would be possible without that information. These benefits have been estimated by Adams *et al.* (1995). The costs are the historical and estimated future costs to the U.S. of the research, development and operational observing system.
The results indicate that TOGA and the successor operational system could provide a real economic return on investment to the U.S. of at least 13% to 26%, depending on assumptions made in a comprehensive sensitivity analysis. Because the hurdle rate for federal government investment is 7%, this particular combination of research and operations is judged to be a sound use of public resources. In summary, the total costs of the 11 year research programmes discounted to 1995 prices was $273 million, the cost of the U.S. contribution to the successor observing system is estimated to be $12.3 million per annum, but the net benefits to U.S. agriculture are estimated to be $240 million per annum – all at 1995 prices.

These results are significant in their own right but are also seminal for the wider economic assessment of the GOOS and other members of the G3OS. Firstly, although not all attributable to marine observations, the estimated annual net benefit of $0.24 billion arising from this one application outside the marine sector is a significant fraction of the ~$1 billion expected to be delivered to the U.S. economy within that sector, based on the scaling approach. Secondly the detailed method used demonstrates how research and operations can be linked successfully in an economic assessment, how varying degrees of skill in a forecast can be treated and how the likely (sceptical) behaviour of recipients of forecast advice may be incorporated, and the sensitivity to assumptions tested.

Although not subject to a CBA, Moura (1994) has noted that grain production in NE Brazil fell to 10% of the long-term mean in 1987, following an ENSO episode when no action was taken in response to a forecast of its incidence. However, when action was taken to select drought resistant crops and conserve water resources in response to the forecast of a similar event in 1992, production was 82% of normal. Similarly, Hammer *et al* (1996) have demonstrated that wheat farmers in northern Australia can increase their profits by up to 20% and/or reduce the risk of an annual loss by up to 35%, if seasonal rainfall forecasts based on the Southern Oscillation Index are used to guide crop management decisions.

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3.3.4 Conclusions and implications for the GOOS

Although further effort to refine the estimates is necessary, there seems little doubt that, integrated across the globe and ***in broad terms, the annual benefits of improved information about the long and short term behaviour of the oceans are likely to be several to many billion dollars against entailed annual costs of capturing and processing data to generate the required information of one or two billion dollars.*** The benefits will not be limited to the marine sector, and will depend in part on our ability to predict the behaviour of both atmosphere and oceans.

To be valuable, sectoral economic data must be gathered in a consistent manner and be obtained from developing as well as developed countries.

The benefits will be highly granular, being very high as a ratio of incremental costs in some sectors, as demonstrated by the above CBA, and negligible elsewhere. But it is in the nature of the atmosphere and oceans that such sectoral benefits always depend, in part, on the availability of data spanning long times and at large distances from where the particular benefits are realised. That dependence becomes greater as the lead time for decisions made by end users of information increases. This means that ***it is very difficult in principle to link specific investment decisions to specific benefits, particularly before the event.***

On this basis, the optimum time to carry out an economic assessment is when continuation of a service, demonstrated in a research programme, is contemplated. Cost benefit analysis provides a robust, practical method of carrying out such assessments and more examples are required to refine the method as applied to the GOOS and to build confidence in the results.

It is fortunate for the GOOS that there has been and remains a very significant investment in its precursors – in the relevant research programmes of WCRP and IGBP (3.4.2 & 3) and in technology, in particular in space (3.6.1). As discussed further in Chapter 5, the above conclusions and ***an incremental strategy, allow justifiable next steps to be taken in implementing the GOOS.***

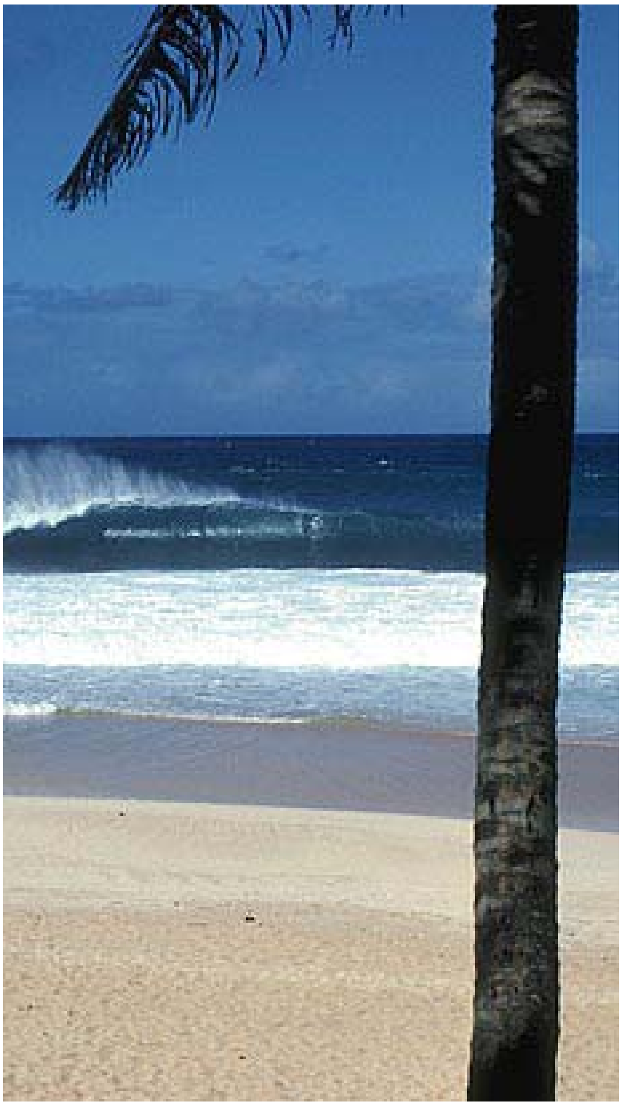
3.4.1

The contemporary and past projects of the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP) are the primary but not sole source of global research of relevance to the GOOS.
These are:

- *for WCRP:*
  TOGA
  WOCE
  CLIVAR
- *for IGBP:*
  LOICZ,
  JGOFS
  GLOBEC

Annex 3 contains a list of the objectives of the current projects. The main results of significance to the GOOS are summarised here.

Many national projects have made major contributions outside these programmes.



3.4.2 World Climate Research Programme

TOGA

The Tropical Ocean Global Atmosphere Programme (1 January 1985 – 31 December 1994) was designed to study seasonal-to-interannual variability and predictability around the globe, with an emphasis on ENSO. In the event, available resources limited the programme largely to studies of ENSO in the tropical Pacific region. In spite of this, TOGA is widely recognised as being the first major success of the WCRP and the substantial progress it achieved is reflected in what can now be done, and what rapid improvements in ENSO prediction are being made.

Conclusions and implications for the GOOS

TOGA has provided:

a. ***improved physical understanding of the climate system.*** A new depth of understanding of ENSO has been achieved; theoretical models for the mechanism of ENSO have been proposed, and the relationship between tropical SST perturbations and the atmospheric response in the middle latitudes is beginning to be unravelled;

b ***an improved ability to measure the upper ocean using enhanced*** **in situ** ***observations.*** Again, partiularly for ENSO in the previously poorly-sampled tropical Pacific, a new capability for observing the surface and near-surface ocean and atmosphere in real time has been developed;

c. ***the development of increasingly realistic coupled ocean-atmosphere models*** particularly of the tropical Pacific Ocean, some of which now demonstrate skill in predicting tropical SSTs months to a year or so in advance; in particular, the predictability of El Niño has been demonstrated;

d. ***the availability of long (in many cases multi-decadal) datasets*** with stringent quality control***;*** in particular for global SSTs;

e. ***more-advanced techniques,*** not only for providing observations, but also for their analysis and assimilation into atmospheric and ocean models.

In essence, TOGA demonstrated that valuable operational services could result from well targeted climate research.

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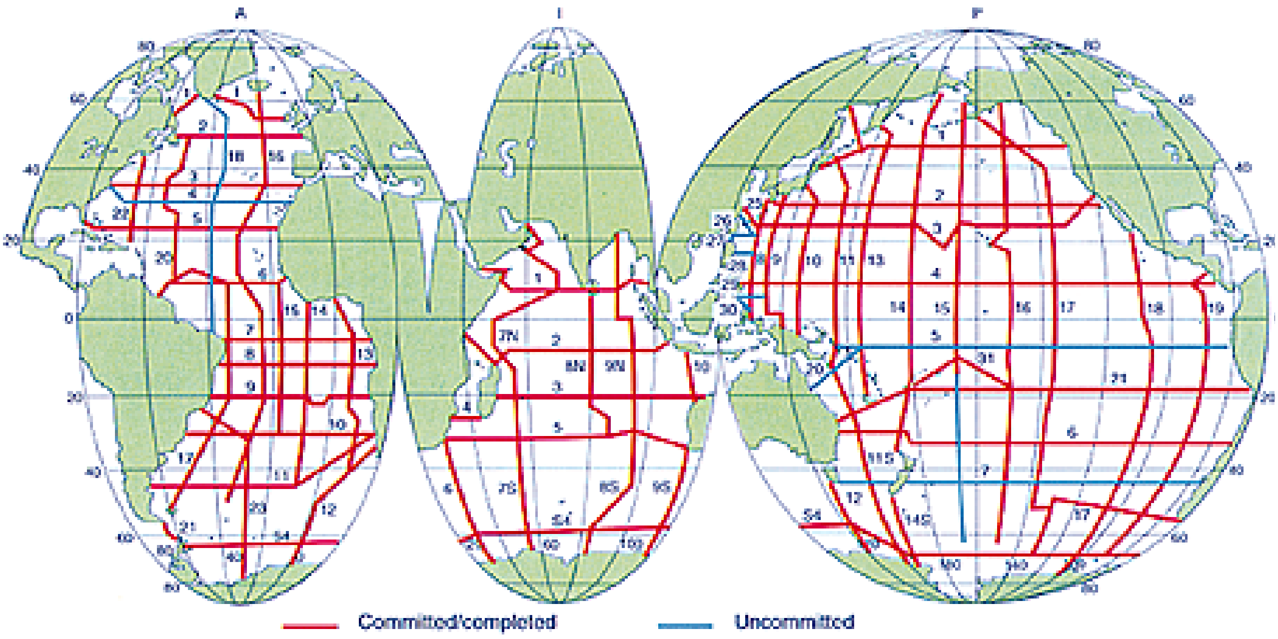
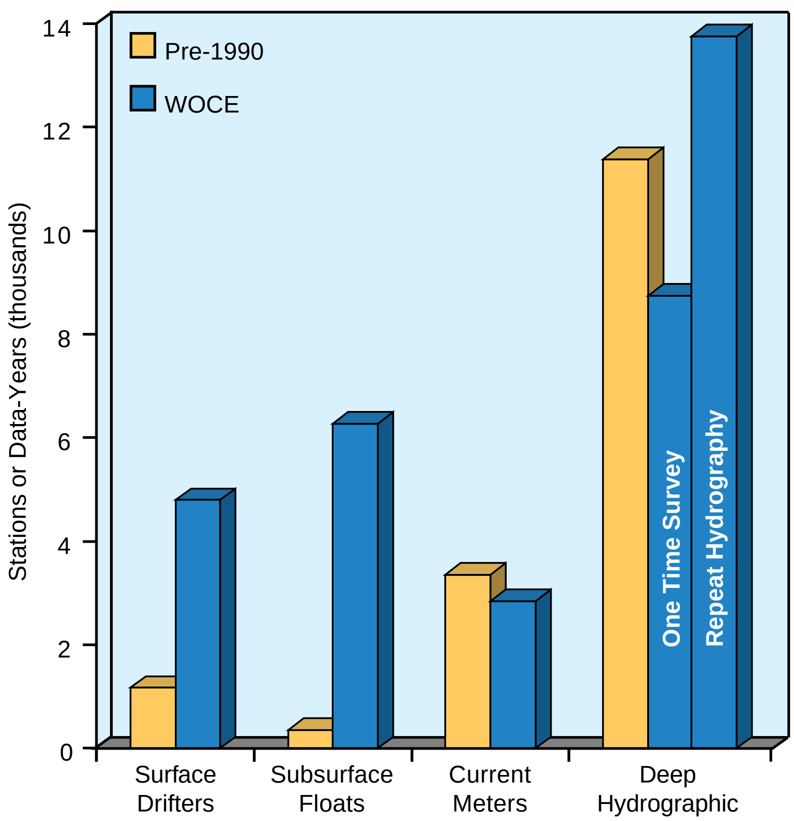


The WOCE One -Time Hydrographic Survey map



WOCE

The principal goal (A3.2.2) of the World Ocean Circulation Experiment (WOCE) is to develop models useful for predicting climate change and to collect the data necessary to test them. This goal is supported by a number of objectives that involve data capture to describe specific aspects of the present ocean circulation and achieve dynamical understanding of ocean processes; such understanding and description are required for progress in validation and improvement of models. The WOCE Implementation Plan (WCRP, 1988) describes how the scientific objectives are to be achieved.

During the field phase of the WOCE (1990-97) the total number of high quality deep ocean stations will have been doubled and a comprehensive suite of tracer measurements created, complemented by direct measurements of circulation from ADCPs, floats, drifters, and moorings. A growing database of measurements from TOPEX/Poseidon and ERS-1 and 2 will be available. Many additional meteorological and sea-level measurements will have been collected.

That field phase has been completed, ocean modelling has moved to a much higher level of simulation than was possible at the beginning of the WOCE, and data assimilation methods are being developed by many groups. The WOCE will continue to the year 2002 to take advantage of the full data set and advances in modelling, for much fuller development of the models and particularly methods for data assimilation. This final phase is called WOCE-AIMS (Analysis, Interpretation, Modelling and Synthesis) phase. The goals and recommended structures for WOCE-AIMS are described in WOCE (1997).

Conclusions and implications for the GOOS

Although a research experiment and not an operational programme WOCE can be seen as an early attempt to implement an observing system for the deep ocean that may contain elements that will be incorporated in a manifestation of the GOOS.
It has developed relevant observational techniques, quality standards, data management practices and has encouraged the improvement of modelling and data assimilation techniques. It had limited resources to address variability within the 8-year observational period and thus a major outcome will be an approximation to the mean state of the ocean during this period and something of its seasonal variability. The WOCE ‘snapshot’ will act as a definitive baseline against which future (and past) change can be measured and the tools developed during the experiment will have a large part to play in solving the time dependent problem. Interpretation of the WOCE data set will also point the way towards identifying the critical measurements that need to be continued for a cost effective monitoring system of that physical component. As with several other projects in the WCRP, the project was designed to be independent of radical new technologies. However it has led directly to the development and improvement of observing technology, (section II.2.2 of WOCE, 1997). WOCE-AIMS should contribute to the optimisation of the composite observing system, that in combination with assimilating numerical models, will provide the physical oceanographic data required to provide climate and other advice that justifies the GOOS. That optimisation will cover both temporal and spatial sampling design as well as the combination of physical variables and the accuracy with which each should be measured.

The further stimulus that the WOCE will continue to give over the next few years ***is to model development and to oceanic data assimilation.*** This is highly significant for the GOOS; in particular for climate prediction on the interannual and longer timescales. Such prediction requires coupled ocean-atmosphere-ice climate models. WOCE’s goal is to develop the global ocean model in that combination. It is expected to have better than 1/12^{o} spatial resolution.

More generally the WOCE planners aspire, “by the year 2007, to have an ocean model with one minute of arc resolution. Such models could yield highly credible representations of the flow of boundary currents over complex topography, and the flow of deep currents through narrow gaps. They would improve estimation of eddy fluxes and would yield values for testing parameterization schemes. Indeed, a small-basin early version would suffice for that purpose. Such a ‘super-model’, with 100 vertical levels or layers, would need about 2-4 Terabytes of RAM — the requirement could well be met in a decade from now”.

Ocean modelling has progressed in less than a decade from single basin simulations to a range of global eddy resolving models. At the present time (WOCE, 1997), it is estimated that there are some 250 prime movers in some 50+ centres, engaged in ocean modelling of direct relevance to the WOCE, and by implication to the GOOS, of which perhaps 10% are involved in model development.

During the next few years with WOCE-AIMS, CLIVAR and GOOS running in parallel, there will be frequent opportunities to ensure that observations identified as critical during the research experiments are taken up by the operational community and integrated into the permanent system. The same dialogue will ensure that, whenever possible, the operational service will make observations of continuing value to the scientific community.

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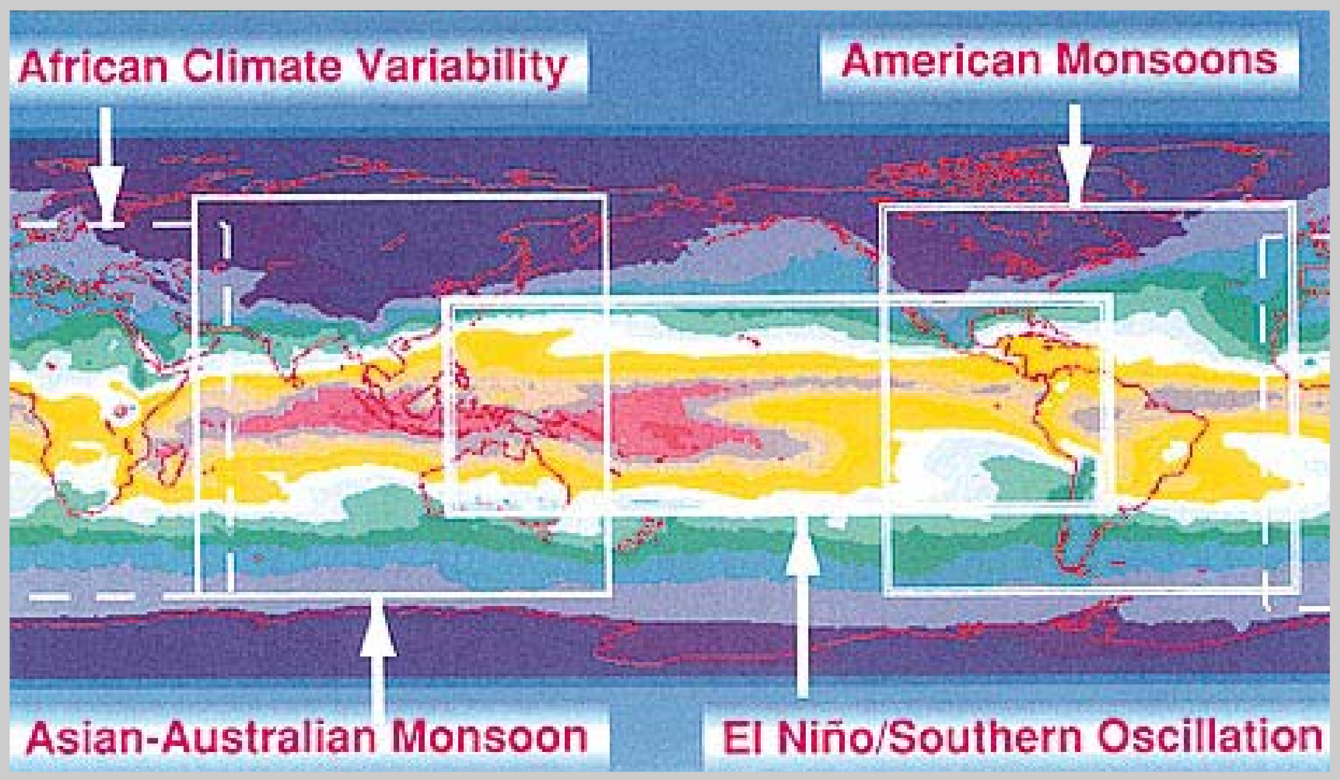
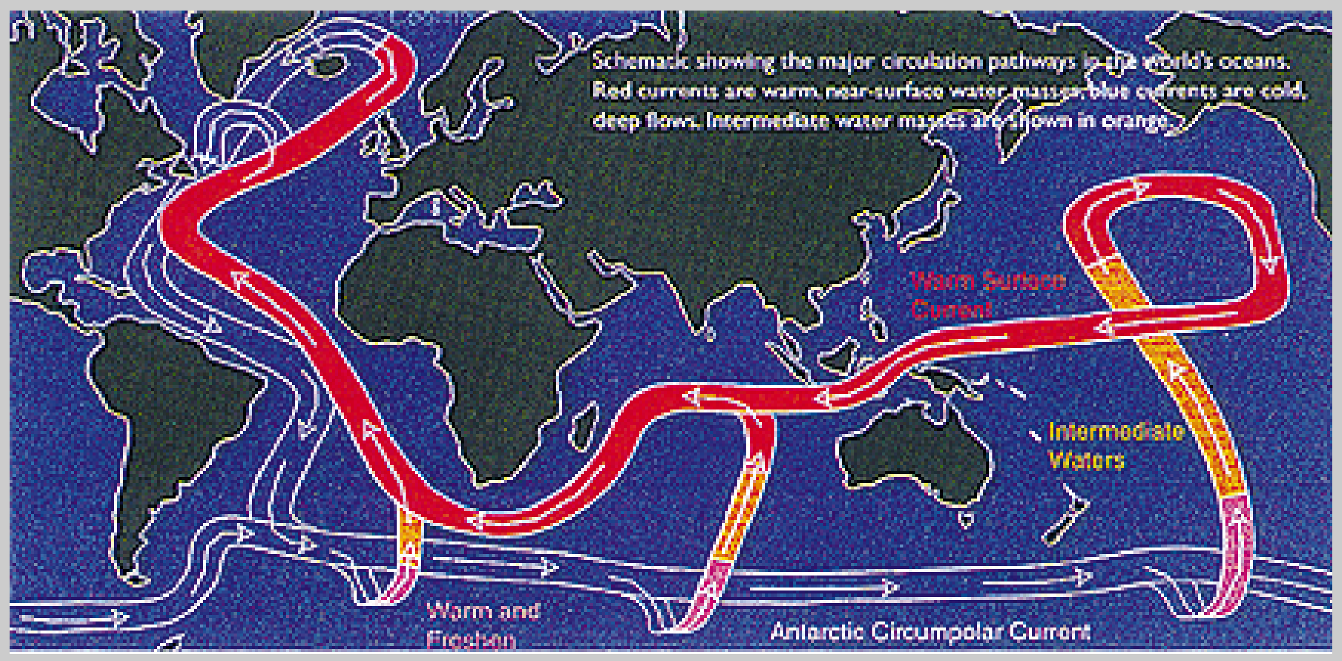


Domains of interest of CLIVAR-GOALS



CLIVAR

The scope and objectives of the Climate Variability and Predictability (CLIVAR) component of the WCRP are set out at A3.2.1. Following the publication of its Science Plan (WCRP, 1995), the current focus is upon the construction of an Implementation Plan that will be introduced in late 1998.

Currently, scientists with interests in the Global Ocean Atmosphere Land System component of the CLIVAR (CLIVAR-GOALS) have identified four important areas of concentration:

- Improving and extending the ENSO predictions, by refining and enhancing the current observing system, and by improving models and data usage.
- Broadening knowledge of the interannual variations of the Asian-Australian monsoon, with a view to providing predictions of onset, strength, variations, and duration and to determine the role of this monsoon on the predictability of the global climate system.
- Increasing understanding of the American monsoon.
- Understanding the interannual variability of African climate and its dependence on sea surface temperature, and determining the prospects for improved prediction.

The CLIVAR-DecCen component has identified five areas of concentration:

- Improving the description and understanding of decadal climate variability in the North Atlantic basin involving the atmospheric North Atlantic Oscillation.
- Documenting and better understanding the decadal variability in the Pacific-Indian Ocean basins.
- Documenting and better understanding decadal variability originating in the tropical Atlantic and its effects on the climates in Brazil and Africa.
- Improving the understanding of inter-decadal variability and the possibilities for sudden climate change associated with the Atlantic thermohaline circulation.
- Investigating the variability in the Southern Oceans.

Three areas of concentration have been identified for the CLIVAR-ACC component:

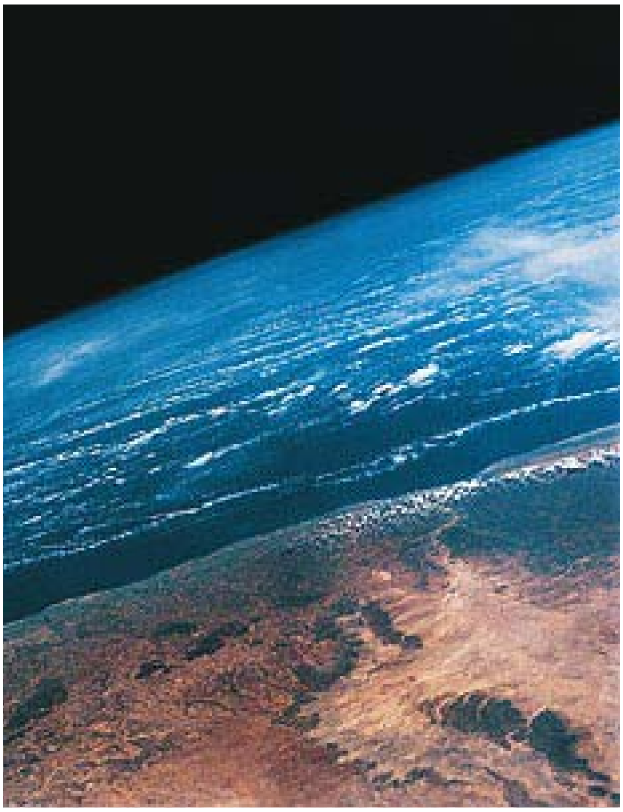
- Reduction of the uncertainties identified by IPCC Second Assessment Report, in predicting the likely rate and magnitude of climate change and sea level rise.
- Detecting anthropogenic climate change over the natural or anthropogenically modified natural variability of the climate system on decadal time scales.
- Reducing the predictions of long term climate change to a regional level so that these predictions can be better shaped for useful applications.

Conclusions and implications for the GOOS

The ocean is the primary memory of the climate system and that SST and associated fluxes of sensible and latent heat are major drivers of atmospheric circulation – on a wide range of scales. Equally, many oceanographic circulations are wind driven and influenced by fresh water returned from the atmosphere. This close, two-way coupling demands coupled observation and modelling of the oceans, atmosphere and land surface processes. ***Prediction of climate, whether of natural or anthropogenic origin, requires the interactions to be understood and monitored.***

At the strategic level, CLIVAR is the programme of research that promises to deliver the understanding and tools which will enable judicious investment in the GOOS observing systems to deliver benefits in the form of climate related services. At the tactical level, as in TOGA, it provides the insight and some of the momentum to help justify and prioritise specific observing systems; as in the case of weather forecasting, the numerical models that enable climate service provision will be developed initially for research purposes.

It would be difficult to overestimate the importance of CLIVAR for the long-term realisation of the GOOS, and the programme will be a major user of observations captured within the context of the GOOS.



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3.4.3 International Geosphere Biosphere Programme

For success IGBP requires coordination of very able but highly distributed local scientific communities. In order to achieve this, IGBP has invested, with the HDP and WCRP, in the fields of training and capacity building, particularly where the maintenance of high measurement standards over long periods of time is required. The Global Change SysTem for Analysis, Research and Training (START), (IGBP, 1991) is the result. ***The GOOS has similar needs and can benefit from the initiative.***

LOICZ

The scope and goals of the Land-Ocean Interactions in the Coastal Zone project are set out in Annex A3.1.3. The project began in 1993 with the establishment of the Core Project Office at the Netherlands Institute for Sea Research.

An Implementation Plan (Pernetta and Milliman, 1995) lays out specific scientific goals and objectives for the project, and identifies activities that are to be carried out and tasks to be completed to resolve identified issues and uncertainties. Four research foci are identified:

Focus 1. The effects of changes in external forcing or boundary conditions on coastal fluxes.

Focus 2. Coastal biogeomorphology and global change.

Focus 3. Carbon fluxes and trace gas emissions.

Focus 4. Economic and social impacts of global change in coastal systems.

Focus 1 recognises that organic production and transformation of nutrients, carbon pollutants and sediments in, and their transport through, coastal systems are strongly influenced by physical and chemical forcing at the land ocean and atmosphere boundaries. Observational and modelling studies are needed to identify and quantify relationships between fluxes of energy and material at system boundaries, and to describe system responses. There is a logical connection to HOTO.

Focus 2 comprises three activities designed to determine how ecosystems affect the form and functional properties of the land-ocean interface, determine how human activities affect coastal biogeomorphology and to determine and, as far as possible, validate scenarios of past and future coastline changes.

The primary objectives of **Focus 3** are to establish the synoptic distribution of key components of the carbon cycle (including nutrients), study the dynamics of carbon in selected coastal systems, assess the reliability of scaling up from such studies and hence develop global estimates of the budgets. The work will be carried in co-operation with JGOFS – see overleaf.

The goal of **Focus 4** is to assess how the responses of coastal systems to global change will affect the habitation and use by humans of coastal areas, and to develop the socio-economic basis for the integrated management of such environments.

The implementation plan for LOICZ calls for six Framework Activities, designed to underpin and enable the efficient conduct of the project. These comprise:

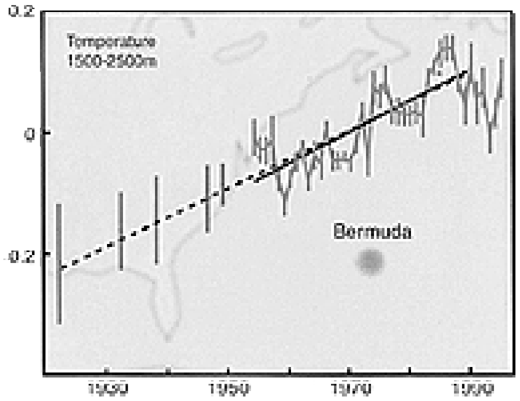
1. ***Scientific networking,*** recognising that the scientific community engaged in LOICZ is widely dispersed and active in many disciplines and that implementation will be through national, regional projects and international programmes.
2. ***Development of a coastal typology.*** A classification is needed that allows the inference of behaviour of some segments by analogy with others that have been studied.

3. ***Adoption of a data system plan.***
4. ***Adoption of measurement standards, protocols and methods.***
5. ***Co-ordination of modelling,*** to achieve development of diagnostic and predictive models.
6. ***Determination of the rates, causes and impacts of sea level change.*** Improved forecasts of the rates of sea level change are required for all four research foci.

Conclusions and implications for the GOOS

The LOICZ is of major significance for the GOOS, the GTOS and interactions between them, particularly through the timely creation of a body of data, expertise, knowledge and tools that are required to meet many of the needs identified by the Coastal and HOTO modules. Specifically, the Networking initiative will create a well co-ordinated body of highly relevant scientific expertise for both the terrestrial and marine environments; the Coastal Typology will be as necessary and relevant to those GOOS modules and to the GTOS, as they will be to LOICZ; and the adoption of standard methods and protocols will assist in the transfer of research into operations. However, it is through the creation, development and validation of numerical models that LOICZ is likely to make a contribution that could not be achieved in any other way. The LOICZ Implementation Plan calls for the establishment and mobilisation of a network of LOICZ modelers throughout the lifetime of the project but proposes specific targets for the publication of the results of their work through the period 1999-2000. This is very timely for the GOOS.

Focus 3 proposes an intensive period of data collection and publication of results for key variables in the carbon cycle, including nutrients and sediments, through to 2000. Again this should spur the development of monitoring methods and assist in the design of long-term networks. Focus 1 should create the understanding and tools that will allow informed, numerate operational management of coastal zones and Focus 4 will be particularly relevant in identifying the specific social and economic benefits that this should bring.



Temperatures between 1.5 and 2.5 km depth near Bermuda show an increase of 0.4°C over the past 70 years. (T. Joyce, USA)

JGOFS

The Joint Global Ocean Flux Study aims to achieve a greater undrstanding of the ocean carbon cycle. The study is administered through the International Project Office at the University of Bergen with support from the Norwegian Research Council. The Science Plan is contained in SCOR (1990) and the Implementation Plan in IGBP (1992). The implementation strategy has been to carry out a combination of large-scale surveys from ships and satellites, studies of important biogeochemical processes to help interpret and interpolate between surveyed quantities and a series of monthly measurements over many years. This strategy provides a means to determine how fluxes and processes vary temporally and spatially. Major JGOFS field observations will cease after 1999. An overarching programme of global synthesis and modelling is expected to continue until 2004 to allow JGOFS to be achieved its stated goals.

In areas of joint interest, biogeochemical modelling is being coordinated with other international programmes, e.g. WOCE, as was much of the CO^2 survey work. JGOFS has an interest in merging its biogeochemical models into global ocean carbon models and there are plans to establish a joint task team with IGBP Global Analysis, Interpretation and Modelling (GAIM). A joint task team, the Continental Margin Task Team, was set up with LOICZ to establish the role of the continental margins as a source or sink of carbon, nitrogen and phosphorous.

The process studies have been conducted in the North Atlantic, the equatorial Pacific, the Indian (Arabian Sea) and Southern Oceans. The most important knowledge gained from these studies includes the identification of ocean regions of CO^2 sinks or sources, the role of phytoplankton in the draw-down of CO^2, the role of microbes in recycling carbon, and the export of carbon to the deep sea and sediments. This fieldwork has provided the best constraints, to date, on regional carbon fluxes into the ocean biosphere and/or release to the atmosphere, that is helping to elucidate the global carbon budget.

Time-series stations have provided important temporal ocean data. The monitoring program is looked upon as a means to understand and monitor future ocean responses to climate. The Bermuda station was established in 1954, and has been occupied some 26 times a year on average, with an enlarged suite of observations since 1976. Some 150 JGOFS cruises have been conducted there since 1989. In 1988, the first JGOFS Time-series Stations were established in the Pacific Ocean near the Hawaii Islands. The Hawaiian station has been in operation for 9 years, with a nominally monthly schedule of visits. Since then, JGOFS Time-series Stations have been established in other ocean regions including the sub-equatorial North Atlantic near the Canary Islands, the southern Indian Ocean near the Kerguelen Islands and in the Northeast Pacific at Ocean Station Papa. The Canary Island station was first occupied in 1991.

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In August 1997, the ocean colour monitoring satellite sensor, SeaWiFS, was launched with strong JGOFS support. Long-term, high quality data are expected from it, to assess global patterns of primary production and carbon fixation by phytoplankton.

Conclusions and implications for the GOOS

The primary contribution that JGOFS will make to the GOOS is in the field of biogeochemical observations: the standards needed, the important variables to be monitored, the treatment of 'scaling' issues, the data management of non-physical observations and the approach to coupled modelling. Improved knowledge of the role played by intermediate level water in the transport and exchange of CO2 will help to design an appropriate long term monitoring network for this important process. There is clear potential for GOOS to adopt some of the methodologies developed by JGOFS.

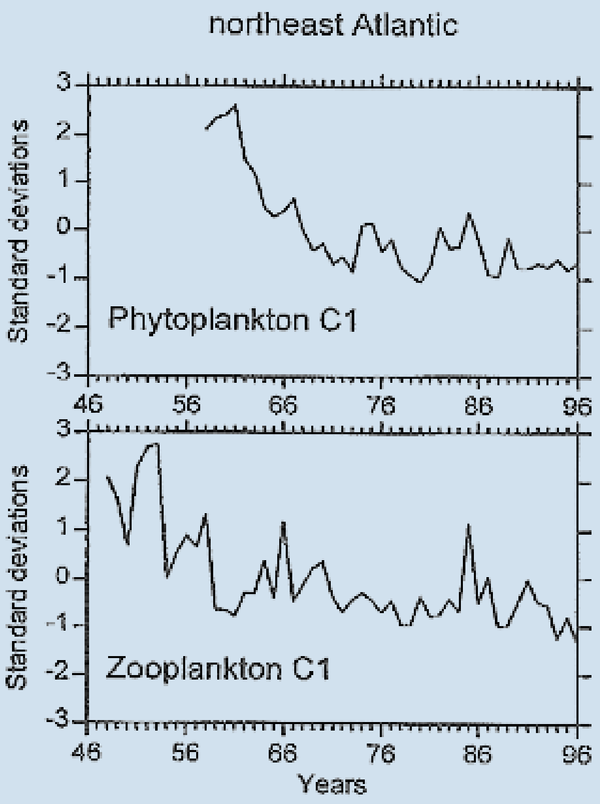
The existence of the time-series stations is also an issue for the GOOS. It is possible that there will be another ocean-atmosphere programme, that will support these stations, but it is also likely that they would form important 'laboratory' sites in any GCOS/GOOS ocean network for climate (GCOS, 1997b). The ability of the GOOS to establish and maintain permanent high quality biogeochemical observations will in turn be a benefit to future research.

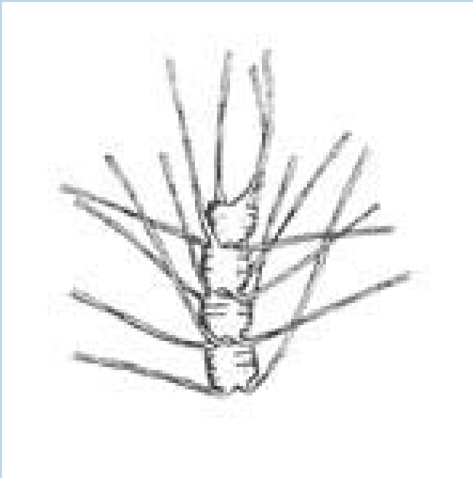
GLOBEC

The Global Ocean Ecosystem Dynamics Project was established by SCOR and the IOC in late 1991. It addresses the need "to understand how changes in the global environment will affect the abundance, diversity and production of animal populations comprising a major component of ocean ecosystems". It also recognised the importance of zooplankton in "shaping ecosystem structure ... because grazing by zooplankton is thought to influence or regulate primary production and ... variations in zooplankton dynamics may affect biomass of many fish and shellfish stocks."

The goal and specific objectives of the GLOBEC are presented at annex A3.1.1. They are to be achieved by concentrating research in four foci:

- Building a foundation for future, global ecosystem models through re-examination of historical databases, synthesis and integration;
- Conducting process studies;
- Developing predictive and modelling capabilities with interdisciplinary, coupled modelling-observational systems;
- Co-operating with other ocean, atmosphere, terrestrial and social global change research efforts to estimate feedbacks from changes in marine ecosystem structure to the global Earth system.





A dramatic multi-decadal decline in plankton biomass has been revealed in the North Sea and eastern North Atlantic by extensive continuous plankton recorder (CPR) sampling. Various explanations have been offered for this decline, and refining these explanations is a challenge for the field of ocean ecosystem dynamics.

The GLOBEC Science Plan (IGBP, 1997) identifies three specific gaps in current knowledge, that it aims to fill:

- the dynamics of zooplankton populations both relative to phytoplankton and to their major predators, fish;
- the influence of physical forcing on these population dynamics, particularly of the dominant variability in circulation patterns;
- the estimation of biological and physical parameters associated with the dynamics of zooplankton relative to phytoplankton.

The early implementation of the GLOBEC includes international projects targeted on the Southern Ocean (SO-GLOBEC) and Small Pelagic Fishes and Climate Change (SPACC). Others are studying specific widespread species, such as *Calanus finmarchicus* on the scale of the North Atlantic. Some national programmes have been initiated to study specific processes such as recruitment into a small number of target species or accessible, well-observed basins of importance to particular national importance, e.g. the Bohai Sea for China-GLOBEC. Collaborative programmes have been initiated with ICES – Cod and Climate Change (Jakobsson, 1994) – and with PICES – Climate Change and Carrying Capacity.

Modelling will focus initially on mesoscale phenomena on spatial scales from km to tens of km, but the nesting concept discussed in Chapter 3 will be employed. In operational use, GLOBEC models are likely to be strongly coupled to their physical counterparts and be capable of assimilating physical, biological and chemical data.

Conclusions and the implications for the GOOS

The upper trophic levels of the marine ecosystem are the most obvious to society and there are many regional examples of observed ecosystem changes at these levels, which have been detected by the sort of long term monitoring that is the hallmark of the GOOS. These include the collapse of the anchovetta and zooplankton stock off Peru in 1972, coincident with a major El Niño event, and those observed in zoo- and phytoplankton abundance in the north-east Atlantic and North Sea observed by the CPR surveys of the SAHFOS, and equivalent measurements in the North Pacific and California current. Many seem to be accompanied by changes in regional physical forcing, but the resulting understanding of cause and effect is at best qualitative or empirical. ***The GLOBEC will play an important role in improving understanding of such ecosystem changes and, where necessary, in devising strategies to deal with their effects.***

The GOOS will benefit from the tools that the GLOBEC should deliver in the form of better monitoring techniques and, in particular, the models that will be developed. GLOBEC models will enable economy and effectiveness in the design of LMR-GOOS monitoring programmes and, in the long term, provision of beneficial advice at both the strategic and tactical levels to governments and industry.

In these senses, the GLOBEC will help to ‘close the loop’ in the delivery of benefits from investment in the GOOS in so far as these relate to the health of the oceans and their use as a sustainable source of food.

In turn, it is to be expected that the GOOS will encourage routine observations beneficial to subsequent research:

- ***the continuation of biological surveys*** to maintain these long term records and their extension to other basins;
- ***the long-term capture of associated physical and chemical data.***

3.4
FOUNDATIONS OF THE GOOS

The science base

3.4.4 Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

GESAMP

was established in 1969. Initially mainly concerned with issues surrounding marine pollution, GESAMP has gradually broadened the scope of its work. It will concern itself with the requirements of the GPA/LBA (3.1.9). It is sponsored by IOC, IMO, FAO, UNESCO, WMO, WHO, IAEA, UN and UNEP. The Group's activities fall into two broad categories:

- preparation of periodic reviews and assessments of the state of the marine environment and identification of problems and areas requiring special attention; and
- evaluation of specific scientific issues, processes and methodologies relevant to management actions for the protection of the marine environment.

Studies published since 1989, that are relevant to the range of monitoring and resulting services being enabled by the GOOS, include topics such as:

- global review of the state of the marine environment;
- global strategies for marine environment protection;
- nutrients as potentially harmful substances;
- evaluation of the hazards of harmful substances carried by ships;
- global changes and the air-sea exchange of chemicals;
- pollution modification of atmospheric and oceanic processes and climate;
- coastal modelling;
- analytical approach to the long-term consequences of low-level marine contamination;
- atmospheric input of trace species to the world ocean;
- significance of carcinogens as marine pollutants;
- priority of organochlorines for marine hazard assessment;
- reducing environmental impacts of coastal aquaculture;
- impact of oil and related chemicals on the marine environment;
- anthropogenic influences on and consequences of sediment discharge to the coastal zone;
- monitoring of ecological effects of coastal aquaculture wastes;
- guidelines for marine environmental assessments;
- indicators of marine ecosystem health;
- invasion of ctenophore *Mnemiopsis leidyi* in the Black Sea;
- sea-surface micro-layer and its role in global change; and
- contributions of science to integrated coastal management.

Conclusions and implications for the GOOS

The evaluations and advice provided by GESAMP are recognised as valuable independent opinion of the highest quality and integrity.

GESAMP's definition of pollution is the basis of the legal definition of this term in UNCLOS (3.1.2).

In 1996, GESAMP launched the preparation of the next periodic global report on the state of the marine environment by the year 2002 – a review that would benefit considerably from implementation of the GOOS.

3.4.5 The International Council for the Exploration of the Sea (ICES)

The work of the ICES is described in A1.3. The development and coordination of cooperative international research and appraisal of exploited marine fish and shellfish stocks have been important parts of the overall programme of ICES activities since the organisation's inception in 1902. Owing to the increase in fishing activity and the resulting need for improved fisheries management, this part of the programme has grown rapidly. Today, more than 120 stocks in various parts of the North Atlantic and Baltic, including all those of commercial importance, are the subject of investigations taking place under the guidance of ICES. It is now possible to conduct age-based assessments for about half of these stocks. but the data available for the remainder restrict assessments to other methods. ICES research work includes the collation and publication of fishery statistics, biological stock monitoring programmes, methodological and theoretical modelling studies, and investigations of biological, ecological, and fishery processes, and the transport of invasive organisms by ship's ballast water.

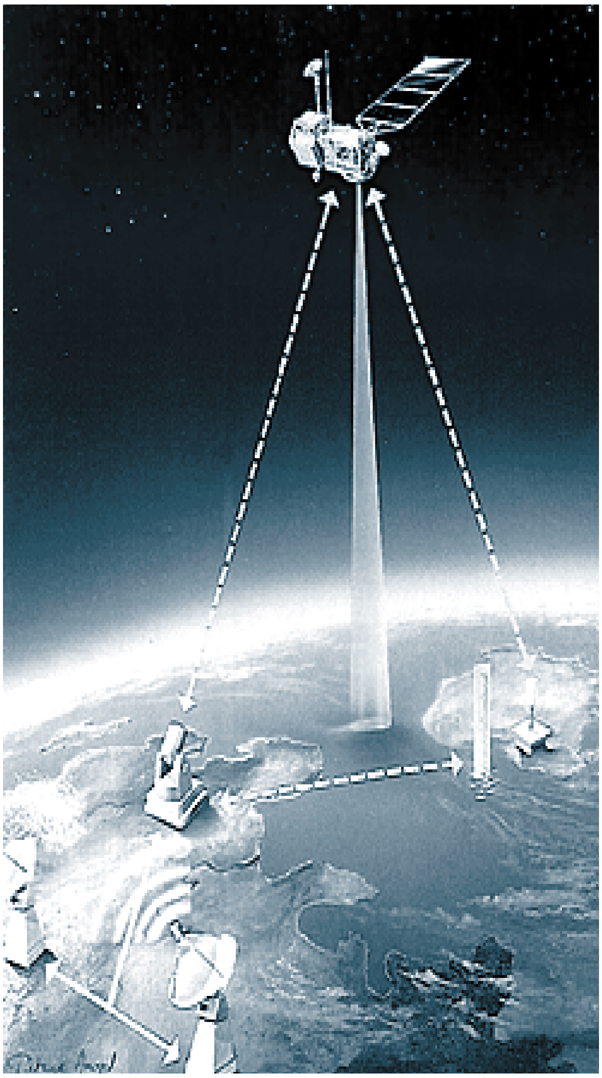
The ICES programme of oceanographic investigations is supported by a large bank of oceanographic data supplied by member countries, dating back to the beginning of the century. The data bank is supplemented by an inventory of more than 11,000 research cruises conducted in the ICES Area during the past 25 years. This inventory includes details of the availability of many types of marine data, including physical oceanographic, marine biological, pollution, fisheries, and geophysical information. The actual value of the resource is limited by restrictions on access to the data banks.

Conclusion and implications for the GOOS

Potentially, the ICES research programme and data banks represent a very significant resource, in particular for the LMR module of the GOOS.

3.5
FOUNDATIONS OF THE GOOS

The technological base



Altimeter mission

3.5.1 Introduction

It is not possible to describe the entire technological base on which the GOOS depends; it is huge and being added to daily. Furthermore, the value of any specific technique is application-dependent, so cannot readily be discussed in the abstract. Chapter 4 reviews the requirement for data and products. Here we outline the technology, that is in place or in prospect, in the form of:

- space-based techniques and instruments for making complementary *in situ* measurements with the accuracy and stability required for GOOS purposes;
- systems for tracking and/or relaying data from low-power, low-cost platforms operating in the hostile marine environment;
- very high performance processors and high capacity data storage systems capable of running numerical models of the resolution and capacity to adequately represent the essential physics, chemistry and biology of the oceans.
- information management and presentation methods and systems.

In section 3.6 we identify existing and planned programmes that are employing these technologies and, as a consequence, are important foundations for the GOOS.

3.5.2 Technology for data capture

Several types of remote sensing instrument have been devised to monitor the oceans, primarily from space but also from aircraft. Acoustics are widely used to measure within the water column. The operating principles of the various generic instruments in use are described as a precursor to the tabulation of the techniques available to measure specific variables.

Technology for data capture

Remote Sensing Instrument Type	Description
-radiometer	a passive instrument measuring upwelling radiation in specific spectral bands; may have a directional capability and be able to distinguish anisotropic and polarisation characteristics
-radar	an active instrument measuring the intensity of microwave radiation after its scattering/reflection by target(s)
-lidar	as for radar but illumination is by a pulsed laser
-imager	a nadir-viewing radiometer or radar capable of producing an image of the earth's surface in the specific spectral band
-altimeter	non-imaging radar whose information content is principally in the transit time of the pulse

Sea surface and near-surface properties

Variable	Method/Sensor	Comments
sea level and topography	radar altimetry	capable of an accuracy of ±5 cm rms currently (e.g. ALT on TOPEX/Poseidon), improving to ±1 cm in future; requires accurate orbit determination, and better description of the geoid (e.g. by GRACE on ESSP)
	tide gauge	detects the level of the air-sea interface or measures pressure from a fixed point below the surface; gauges can be fixed to 1 or 2 cm in a geocentric frame of reference with the aid of the GPS.
sea surface temperature	Infrared radiometry	typically measures temperature to an accuracy of better than 0.5°C in the absence of cloud and /or substantial aerosol loading and with a horizontal resolution of a few km (e.g. AVHRR on the NOAA missions); dual path methods provide corrections for aerosol and water vapour loading (e.g. AATSR on ENVISAT)
	aircraft and ship-based radiometry	benefits from a short path length and avoidance of cloud
	in situ measurement by thermistor or resistance thermometer	can be mounted on a wide range of platforms, e.g. in engine water intakes or as hull mountings on ships, on moored and drifting buoys or floats; an accuracy of 0.1°C is achievable;
surface and near surface salinity	conductivity sensor	has been used successfully on moorings, drifters, CTD probes, and in the form of thermosalinographs on VOS; has been trialed on towed vehicles
	satellite-borne microwave radiometry	L-band and S-band emission are under examination; requirement is for ±0.1 ppt
surface and sub-surface currents	drift	of ships and buoys; requires removal or minimisation of drift due to wind near surface effects.
	acoustic Doppler current profiler	can be upward pointing from the sea bed or downward pointing from buoys a range of vessels and platforms
	coastal HF radar	measures the component parallel to the radar beam to a range of 20 to 50 km from systems operating above 25 Mhz, to 200 km from lower frequency systems
	altimeter	large scale currents are inferred from sea surface topography (e.g. SSALT on TOPEX/Poseidon)
sea surface waves	altimeter	responding to long period waves
	synthetic aperture radar	from the image variance (e.g. ASAR on ENVISAT)
	coastal HF radar	accuracy is similar to that of the wave-rider buoy
	accelerometer/ pressure sensor	for deployment on wave-rider buoys and ships visual observationfrom ships and offshore platforms
	model estimation	dependent upon good estimates of atmospheric forcing fields
surface wind	scatterometer	scanning microwave radar; backscatter from capillary waves is related to wind speed (±2 m/s) and direction (±20° with a 180° ambiguity) (e.g. ASCAT on METOP)
	altimeter	operating as a nadir-pointing radar; wind speed only (e.g. RA on ERS-2)
	radiometer	scanning microwave; wind speed only, typical accuracy ±1.5 m/s (e.g. AMSR onADEOS2)
	visual observation	of sea state from ships
	anemometer	on offshore platforms and moored buoys; ±1m/s, ±10°
	drift	of untethered buoys designed to be wind sensitive
	NWP estimation	may be useful in unmonitored areas and to remove ambiguity of scatterometer measurements
sea ice	altimeter	microwave - high vertical but coarse horizontal resolution (e.g. RA on ERS-2) lidar - improves horizontal resolution (e.g. GLA on EOS)
	scatterometer	±10% and type; (e.g. ASCAT on METOP)
	radar	all-weather measurement of ice topography; (e.g. SAR on RADARSAT)
	imaging radiometer	visible and infrared, few km resolution; cloud limited (e.g. AVHRR on NOAA missions) microwave, ±10% (e.g. AMSR on ADEOS 2)

3.5
FOUNDATIONS OF THE GOOS

The technological base

Variable	Method/Sensor	Comments
biological activity	imaging radiometer	visible and near infrared wavelengths - ocean colour; aircraft (e.g. CASI) or satellite based (e.g SeaWiFS on OrbView 2)
	fluorometer	for chlorophyll concentration, mounted on surface floats, voluntary & research ships, moored buoys and platforms
	water sample	for laboratory analysis
	plankton sampler	nets and light traps on platforms and on towed bodies, for subsequent taxonomic analysis
	automatic cell counter	phytoplankton and bacteria assessment
	acoustic Doppler backscatter	zooplankton biomass measurement
	automated video indentification	zooplankton recognition and quality
	satellite imagery	coastal maps showing habitat distribution, mangrove, mud flats, coral reefs etc.
	towed plankton recorder	trans-oceanic sections recording plankton samples
chemical properties	electrochemical (specific ion or molecule) sensors	capable of measuring: pH, salinity and the sea water concentration of metals, carbon dioxide, dissolved organic carbon, dissolved oxygen, nutrients etc.
	photometer	optical detection of chemical reactions
suspended sediments	imaging radiometer	visible and near infrared wavelengths - ocean colour; aircraft (e.g. CASI) or satellite based ((e.g. SeaWiFS Solids on OrbView 2)

Associated near-surface meteorological measurements

pressure	straingauge	from offshore platforms, buoys and ships, ± 0.1 hp
temperature	resistance thermometer	from offshore platforms, buoys and ships, ± 0.10C
humidity	electrochemical	from offshore platforms, buoys and ships, ± 5%
visibility	forward scatter	subject to sea salt contamination
rainfall	imaging radiometer	visible and infrared, inferred from cloud depth (e.g. AVHRR on NOAA missions) microwave emission (e.g. TMI on TRMM)
	radar	horizontally, 3-5 cm on ships and in coastal regions; vertically, from space (e.g. PR on TRMM)
	gauge	ship-mounted, optical or volumetric, spray difficulties
	acoustic	sub-surface measurement of rain generated noise
	NWP	comparable accuracy to direct measurement at sea
short wave radiation	radiometer	research vessels, VOS and buoys - requires spray protection and gimbal mounting; inferred from geostationary satellite cloud monitoring

Interior ocean and sea bed properties

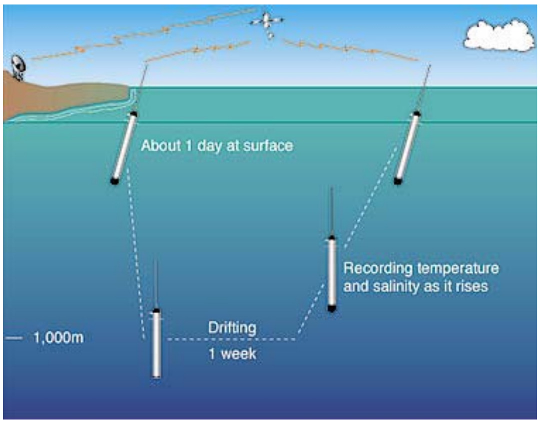
Variable	Method/Sensor	Comments
bathymetry	acoustic echo sounder	hull-mounted, multi-beam or from a towed platform
	satellite altimetry	variations in sea level caused by bottom topography
upper and deep ocean thermal and salinity structure	resistance thermometer conductivity and pressure sensor	for temperature and salinity profiles: on recoverable hydrographic ocean thermistor chains, CTD probes and autonomous vehicles for the deep ocean: plus expendable (XCTD) packages and the PALACE float for the upper ocean. without the conductivity sensor, for temperature profiles only in the upper ocean, on XBT; temperature and salinity measurements from moored buoys (e.g. the ATLAS moorings in the TAO array)
	speed of sound	for large scale monitoring of temperature perturbations
currents	acoustic Doppler current profiler	sea-bed or moored buoy mounted; a few cm/s
sediment loading & transport	optical acoustic transmissometer & backscatter	sea-bed mounted

The technological base

Moored Buoys

There is a wide range of data buoys available for mooring in both deep and shallow water, and from which relevant meteorological and oceanographic measurements can be made (Miendl 1996, Hansen and Stel 1996, Knauth et al,1996,). A typical sensor suite, on the ATLAS Buoys developed by NOAA's PMEL for deployment in the TAO Array (3.6.6), measures wind at +4m, air and sea surface temperature, relative humidity, 10 sub-surface temperatures from -20m to -500m and water pressure at 2 depths. Data collection is via Service Argos (3.5.3). Each buoy is visited annually for maintenance/replacement purposes. Operational buoys have also been instrumented to measure barometric pressure, visibility, solar radiation, directional and non-directional wave properties, surface and salinity profiles, current profiles using ADCPs, radioactivity, turbidity, dissolved oxygen, chlorophyll and nutrients (orthophosphate, nitrate, ammonia). Sensor fouling by marine organisms limits the operational life of sub-surface optical and chemical sensors to a few months.

Deploying an ATLAS mooring L.Stratton TAO Project office



PALACE – Profiling Autonomous LAgrangian Circulation Explorer Jack Coats Woods Hole

The ALACE float (Davis, 1992) is a neutrally buoyant float that drifts with current on isopycnic surfaces (as deep as 2000m) and ascends to the surface to transmit position data via Service Argos. This occurs from once a week to once a month to define characteristics of the broad scale circulation. The addition of a temperature sensor enables the float to furnish a temperature profile on the ascent, and conductivity sensors are being added to many to provide salinity profiles; such floats are known as PALACE floats. The ALACE float was deployed extensively during the field phase of WOCE and, with a lifetime of up to 5 years and a modest price (~$10k), is likely to be an important device for the GOOS. Deployment would be from ships of opportunity.

Autonomous underwater vehicles

Millard et al (1997) have described the current status and objectives of a project whose aim is to develop AUVs for use by the marine science community. The goal over the next 3 years is to produce a vehicle capable of collecting physical, chemical and geophysical data down to depths of 2500m with a range of 1000km. The current demonstrator has a range of 60km and a maximum operating depth of 500m. It cruises at 2 m s-1 , uses bottom tracking ADCP and forward looking collision avoidance sonar below the surface and GPS on the surface for navigation. It is expected to use 2-way satellite communications, both for control purposes and to transmit data between profiles. Initially it is expected to use the vehicle in shelf and shelf edge scientific missions, but in the long term is seen as a more cost effective method of making the sort of WOCE transects that require dedicated research vessels at present. The possibility of using AUVs in an adaptive sampling mode has been noted by Nadis (1997). McCoy and Jacobs (1996) have described an Autonomous Profiling Vehicle, for shallow water, near-shore use.

3.5
FOUNDATIONS OF THE GOOS

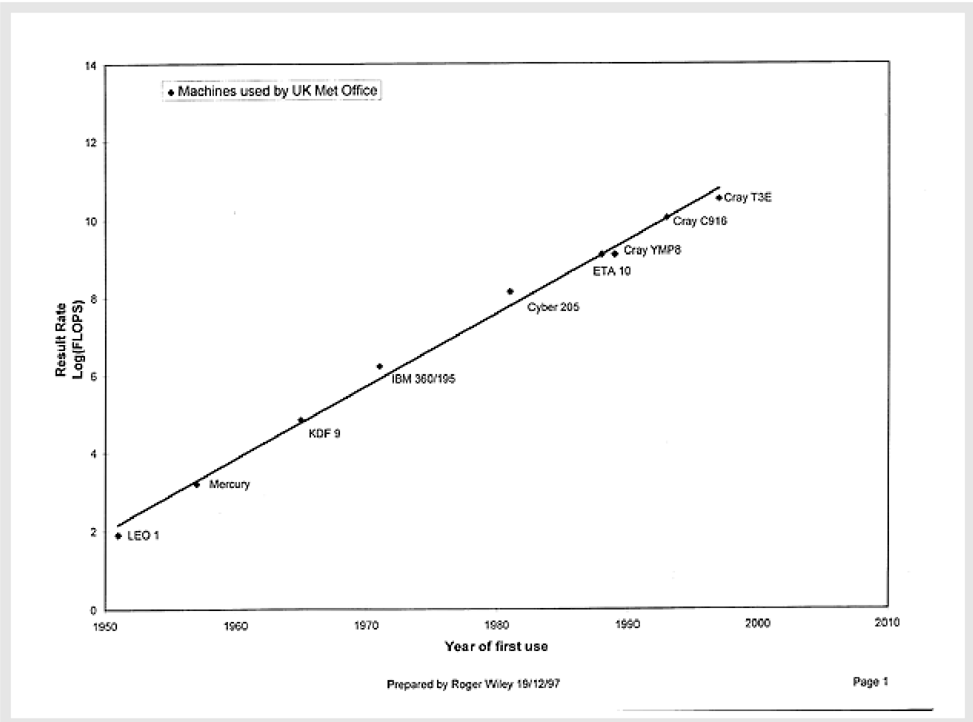
The technological base

Acoustic tomography

Munk and Wunsch (1979) proposed this technique, that relies upon the measurement of perturbations in the travel time of acoustic pulses to infer perturbations in temperature, density and velocity. In its most general form, many sources transmit such pulses to many receivers, with typical separations of 100km to 1000 km. Experiments have also been conducted in the West Mediterranean.
Munk (1994) has pioneered a particular system that he has described as 'Acoustic Thermometry of Ocean Climate' (ATOC). It comprises a sound source and one or more receivers separated by between 5000 and 10000 km. The time of travel of a pulse of sound provides a measure of the average temperature at a depth of about 1km along a great-circle path between the transmitter and receiver(s). If repeated at regular intervals over a long period of time such measurements offer a promising way of detecting long term trends on the scale of the general circulation of the oceans.

The Jason mission

It is planned to launch the Jason-1 mission in early 2000 to continue the collection of data, started with TOPEX/Poseidon, on the height of the sea surface above a reference ellipsoid. The topography of the sea surface obtained in this way allows the large scale circulation, and hence transport properties of the ocean to be inferred. Two measurements are required. First the satellite range above the sea surface from an altimeter and then the radial distance from the satellite to the reference ellipsoid based on a precise determination of the orbit. The altimeter measures the time taken for radar pulses to travel between a transmitter to sea surface and back to a receiver on the satellite. The shape of the echo also allows wave height and wind speed to be estimated. Corrections are necessary to compensate for propagation delays incurred in the ionosphere and troposphere. A two frequency altimeter (Poseidon 2) is used to obtain the ionospheric correction. A three frequency radiometer provides the information to make the tropospheric correction. The orbit is determined using data from a terrestrial networks of some 50 Doris beacons and 150 GPS receivers, and an on-board GPS receiver. A laser retroreflector provides a reference target for occasional laser tracking measurements.



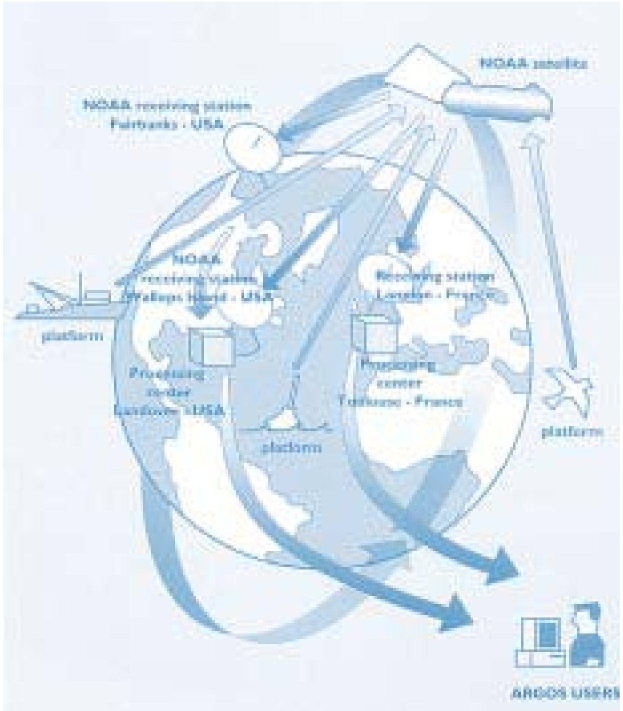
Performance of state-of-the-art computers in their first year of operation

3.5.3 Technology for data collection and position fixing

Data can be collected from surface platforms by general purpose communication systems or those designed specifically to collect environmental information. INMARSAT and other commercial systems supplying the market for mobile communication services are examples of the former; Service Argos on the NOAA satellites and the Data Collection System on a number of geostationary meteorological satellites are examples of the latter. Sub-surface data collection is either by cable (conductive or fibre optic) or by acoustic telemetry.

Several systems exist to determine the position of data collection platforms. Satellite based methods are suitable for platforms at or above the sea surface. Acoustic methods are used below the sea surface.

- The Argos system is able to fix the position of a mobile platform carrying a suitable transmitter to within 0.3 km. This is achieved by measuring the Doppler shift of the transmission at the satellite.
- The GPS consists of 24 operational satellites spaced in orbit so that at any time a minimum of 6 satellites are in view to users anywhere in the world. Each satellite transmits an accurate position and time signal. The platform receiver measures the time delay for the signal to reach the receiver, that is the direct measure of the apparent range to the satellite. Measurements collected simultaneously from four satellites are processed to solve for the three dimensions of position, velocity and time.
- Subsurface floats freely drifting at prescribed pressures can be tracked to provide direct measurements of the oceanic circulation. These floats, named SOFAR for “SOund Fixing And Ranging”, emit acoustic pulses, typically at 300 Hz, once a day. The pulses can be used to calculate the floats’ positions from their times of arrival at listening stations moored near the so-called SOFAR channel depth at known geographical positions. It is possible to use the principle in reverse: the RAFOS float receives acoustic signals instead of transmitting them. At the end of its mission, it surfaces by dropping a weight. All the information collected, including the times of arrival of pulses sent by sources at known geographical positions, are forwarded via the Argos system.
- New commercial satellite communications systems are being installed during 1998 which will provide even greater flexibility and higher data rates for all kinds of communications.



3.5.4 Technology for numerical modelling and data assimilation

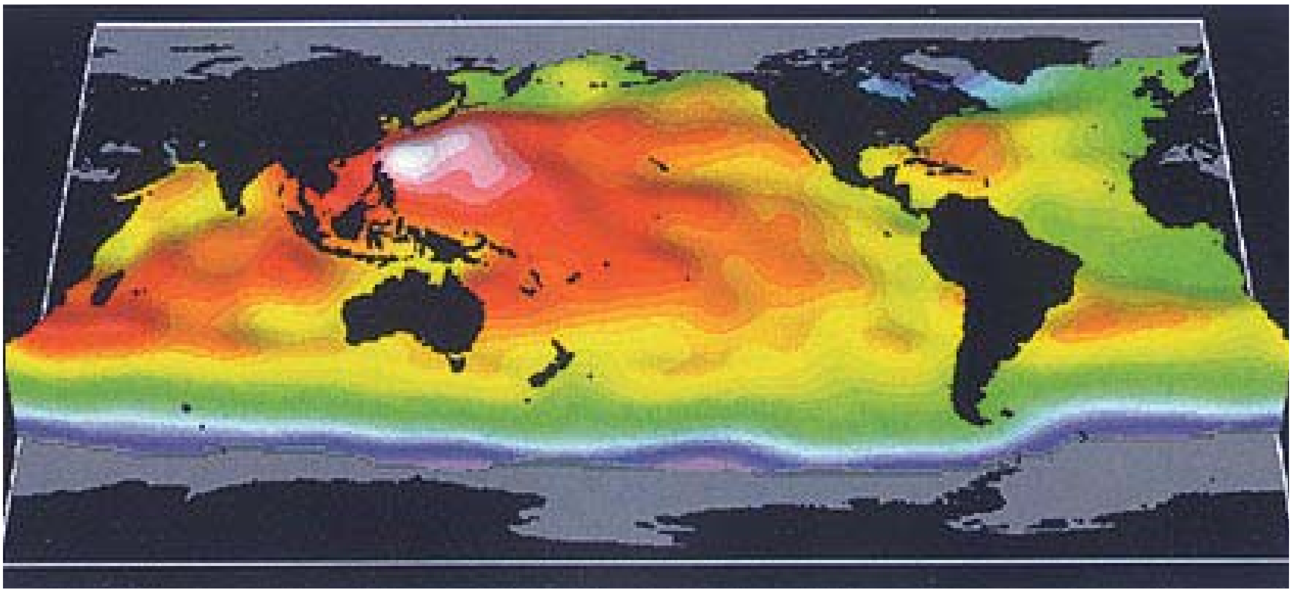
It has been estimated (Woods,1985) that a computer operating at a sustained rate of ~10^{12} floating point operations per second (a teraflop processor) having ~10^{12} bytes (a terabyte) of fast storage available is required to assimilate data into and run an eddy-resolving global ocean model in near real-time. The critical item in this combination is the sustained teraflop performance; terabytes of storage are available to-day.

Wiley (1997) has analysed the sustained performance achieved by the UK Met Office in the first year of operation when running an operational global atmospheric model on a series of state-of-the-art high performance machines. (See figure on page.50). The performance is achieved on operational code not code optimised for a particular architecture. Normally, the performance of a operational model will improve through the life time of a particular computer as both the model and machine are tuned.

In moving from one machine to the next, improvements in performance have been achieved by a combination of architectural changes, such as the vector pipelines of the Cyber 205 and the use of some 700 parallel processors in the Cray T3E, and technological advances, typically resulting in a faster clock speed. The resulting trend line represents a performance enhancement of a factor of 75 per decade.

On the assumption that this trend line will be sustained in future, commercially available machines, capable of delivering sustained teraflop performance when running high resolution global numerical models of the atmosphere or ocean, will be available by 2003.

The technological base



Sea Surface height from TOPEX/Poseidon satellite. Currents are strongest where slopes are greatest JPL, USA

3.5.5 Technology for information management and presentation

All trends in this field point towards increasing volumes of data, the synthesis of data from multiple sources and demands for transparency, accessibility and ease of use. This is an area of technology in which the marine sector should follow, not lead, the development of consumer IT solutions. Typically, this requires adoption of industry standards and implementation of stand-alone and networked Personal Computers or more powerful workstations, running data bases and Geographic Information Systems (GIS) and having/providing wider access via the Inter- or Intranets. This approach is as applicable to developed as to developing countries.

Advanced techniques for the processing and presentation of data and information products are also important, including visualisation software, and methods of selecting and simplifying information for each customer.

3.5.6 Conclusions and implications for the GOOS

There is an impressive range of* in situ *and remote sensing technologies available to capture, collect and communicate physical oceanographic data. There has been dramatic progress, in particular, in devising and equipping automated, autonomous platforms and packages for these purposes. There is more to do to automate biological and chemical data capture techniques in the hostile marine environment.

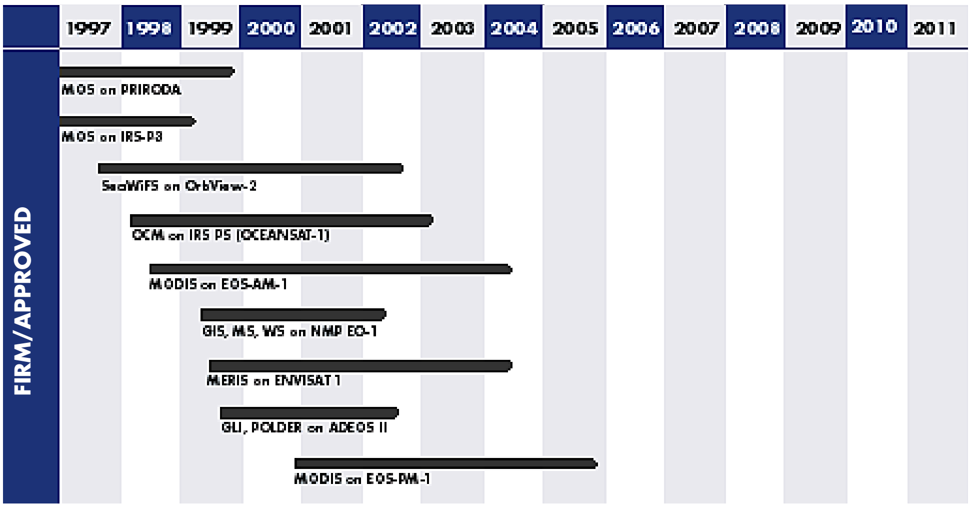
Over the next few years, operational oceanography should be able to take full advantage of the competitive, commercial supply of communication, navigation, powerful processing, high-volume storage, visualisation and desktop computing technology.

3.6.1 Satellite programmes

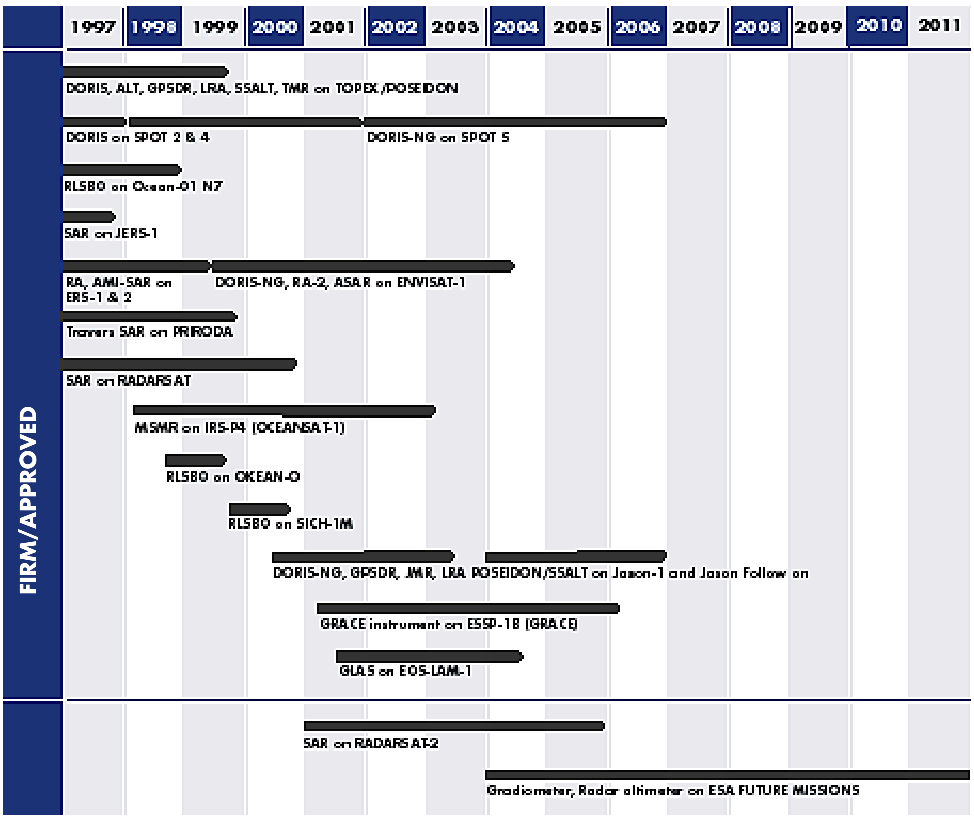
WMO (1996) contains a comprehensive review of the polar orbiting satellites that are providing operational or demonstration data services of relevance to the marine meteorological and oceanographic services of the GOOS. CEOS (1997) updates and extends this by reviewing all the declared Earth Observation and associated data collection missions of the CEOS members.
The figures below are from CEOS (1997).

Briefly the assets that form part of what are, or are expected to be, long-term programmes capable of contributing to the GOOS comprise:

- the NOAA TOVS/ATOVS series of satellites and the US Defense Meteorological Satellite Program (DMSP) that are expected to converge to a US National Polar-Orbiting Operational Environmental Satellite System (NPOESS) in the second half of the next decade. A European contribution to the System called the European Polar System (EPS) is planned to begin with METOP-1 in 2001. The relevant instruments/ capabilities on these satellites are:
  - the Advanced Very High Resolution Radiometer (AVHRR) maintaining, in particular, the long-term record of SST and ice coverage;
  - the Special Sensor Microwave Imager (SSM/I) for wind speed and ice coverage;



Missions for ocean colour



Missions for ocean topography

3.6
FOUNDATIONS OF THE GOOS

The operational base

- the Argos data collection system;
- the Infrared Atmosphere Sounding Interferometer (IASI) for SST and the ASCAT scatterometer for wind speed and direction on the METOP mission.

● the SPOT, LANDSAT and IRS series of satellites providing very high resolution imagery, inter alia, for ecosystem monitoring. The IRS-P4 mission of the ISRO, designated as OCEANSAT-1 is due to be launched early in 1998. It will carry the Multi-spectral Microwave Scanning Radiometer (MSMR) for SST and wind speed measurement and the OCM for ocean colour measurements.

● the geostationary meteorological satellites – GOES, METEOSAT/MSG, GMS/MTSAT, INSAT, FY and GOMS – of the NOAA, EUMETSAT, GMS, ISRO, CMA and RSA, providing continuous medium resolution visible and infrared imagery and, in some cases, a data collection capability.

● the METEOR series of ROSHYDROMET, carrying visible and near infrared sensors for ice cover measurements.

● the TOPEX/Poseidon and follow-on Jason missions of CNES/NASA carrying a dual frequency radar altimeter with precise orbit determination. In this connection the ESSP mission of NASA in 2000, carrying the Gravity Recovery and Climate Experiment (GRACE) for accurate determination of the geoid, is significant.

● the European Research Satellite (ERS-2), expected to continue in service until the launch of ENVISAT in 1999. ERS-2 carries:

- the Active Microwave Instrument (AMI) capable of operating in a synthetic aperture radar imaging mode and as a scatterometer;
- the Along Track Scanning Radiometer (ATSR) for SST and ice cover measurement;
- a radar altimeter.

ENVISAT is expected to have a lifetime of 5 years and will carry:

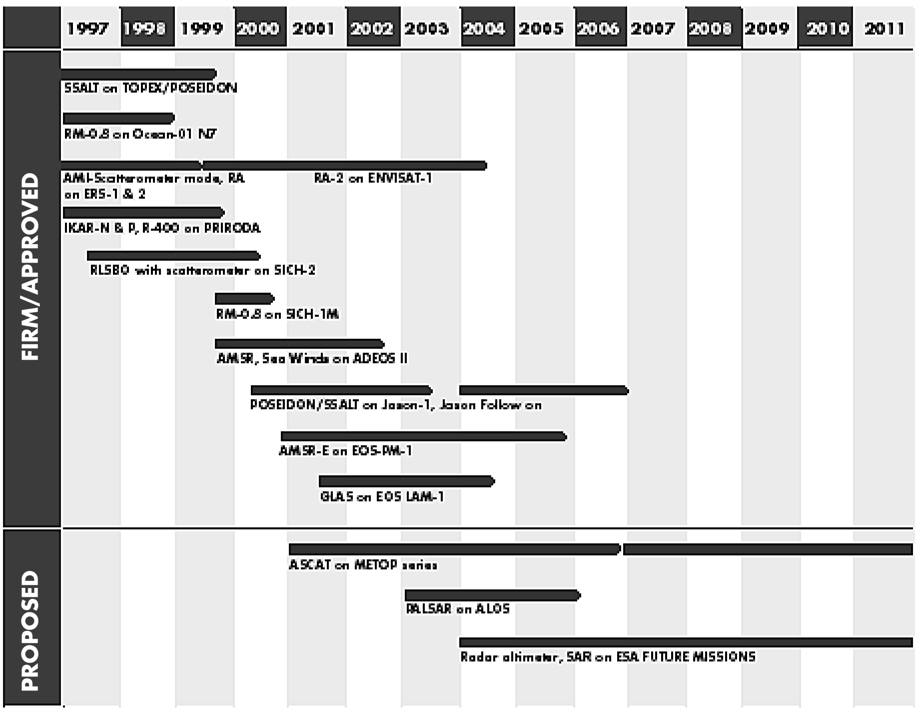
- an Advanced Synthetic Aperture Radar (ASAR)
- an Advanced Along-Track Scanning Radiometer (AATSR)
- a radar altimeter (RA-2) with Doris-based orbit determination
- a Medium Resolution Imaging Spectrometer (MERIS) for ocean colour.

● the RADARSAT missions of the CSA carrying a SAR for all-weather monitoring of ocean and ice surfaces.

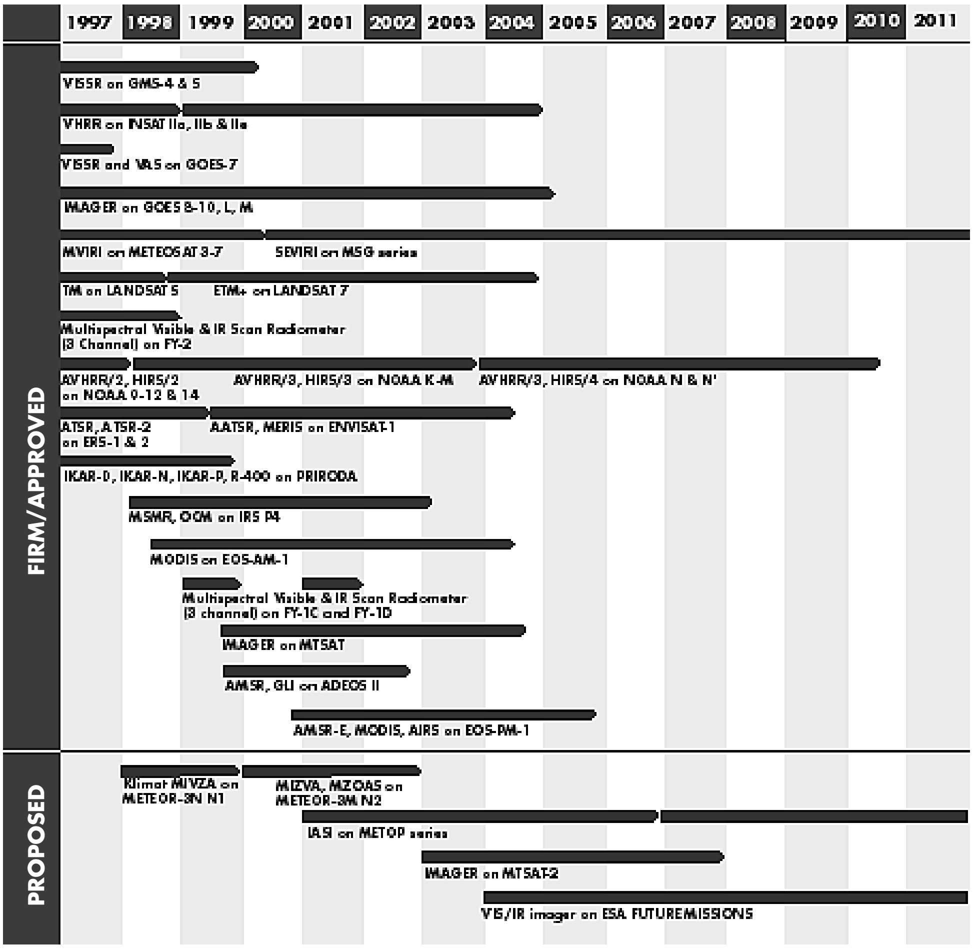
● the Orb View mission of NASA carrying the Sea WiFS ocean colour sensor.

● the EOS AM and PM missions of NASA carrying the Moderate Resolution Imaging Spectrometer (MODIS) for SST, ice cover and ocean colour measurements. The EOS is expected to carry the Advanced Microwave Scanning Radiometer (AMSR) also for SST, wind speed and ice cover measurements.

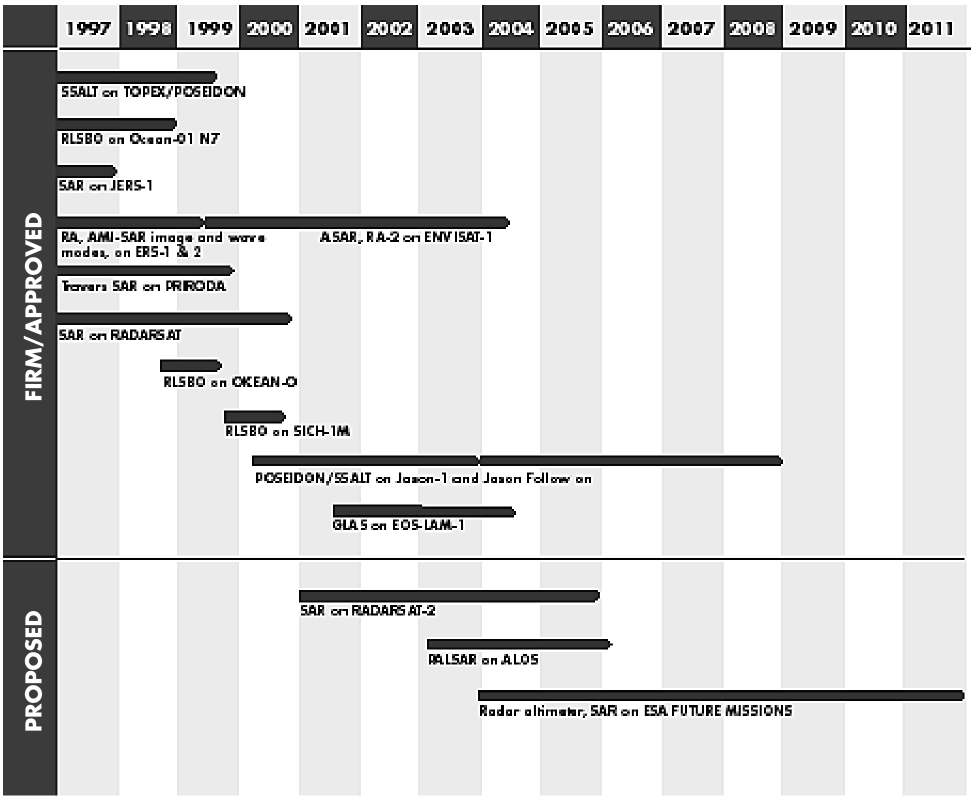
● the Advanced Earth Observing System (ADEOS-2) of NASDA carrying the GLI and POLDER imaging radiometers for ocean colour, the GLI-AMSR combination for SST and the Sea Winds scatterometer for wind speed and direction.



Missions for sea surface winds

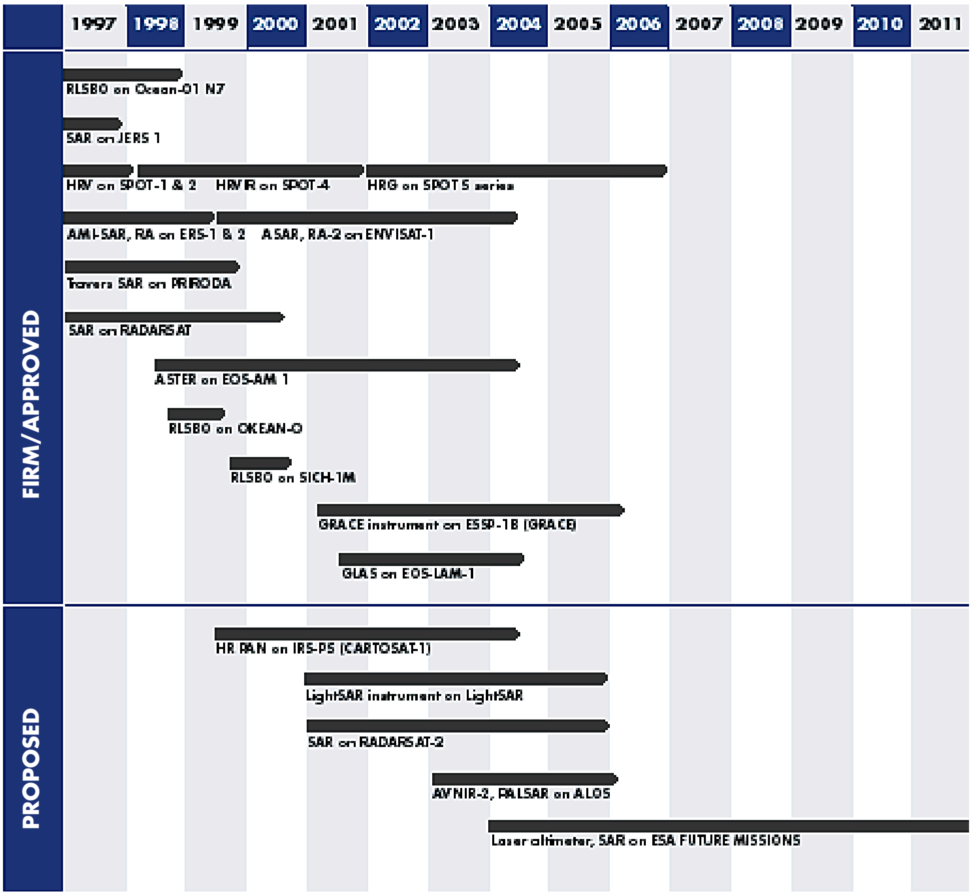


Missions for sea surface temperature

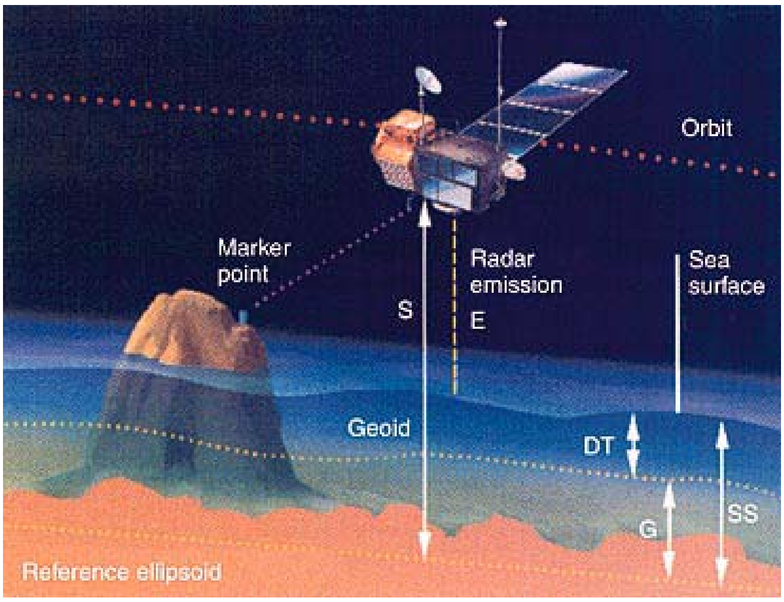


Missions for wave height and spectrum

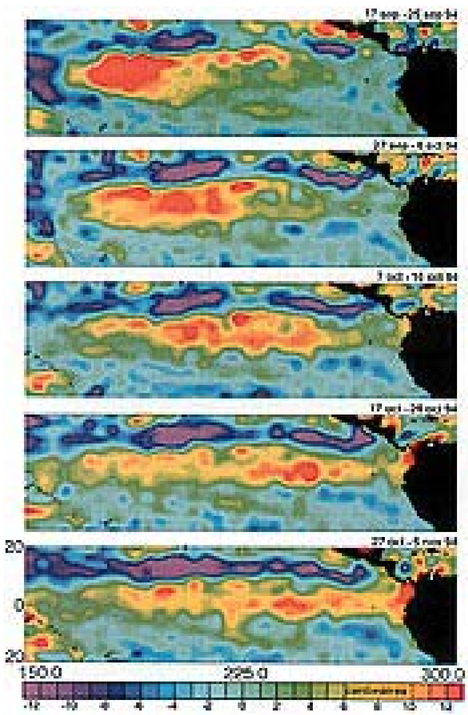
The operational base



Missions for ice sheet topography



Radar altimeters measure the distance between the satellite and the sea surface (E). The distance between the satellite and the reference ellipsoid (S) is derived by using the Doppler effect associated with signals emitted from marker points on the Earth's surface as the satellite orbits overhead. Variations in sea surface height (SS, ie S-E), are caused by the combined effect of the geoid (G) and ocean circulation (dynamic topography, DT)



TOPEX-POSEIDON data shows the elevation of the reference level of the ocean surface. Positive anomalies correspond to areas of upwelling warm water. These data assist in the prediction of El Niño events

Conclusions and implications for the GOOS

Implementation of the GOOS has to accommodate the fact that space based observations derive from instruments and missions that have a long lead time, and are designed currently without the sort of close coordination with *in situ* observation programmes that the IGOS is attempting to achieve. This is a challenge for the G3OS. Furthermore many of the above are demonstration missions, with no commitment to long term continuity. Nevertheless: ***if currently approved and planned EO missions come to fruition there will be provision, up to at least 2005, of satellite data in the form of:***

- ***sea surface temperature measurements whose accuracy and stability are marginally less than desired, and for which complimentary*** **in situ** ***measurements are required. The number of missions planned suggests that continuity will be maintained.***
- ***wind speed and direction measurements from scatterometers to an accuracy that is within about a factor of 2 of the goal of 1m/s and 10 degrees. However the number of missions and their swath widths are less than desirable and a failure of any one mission will be a cause for concern. There is a reasonable provision of planned wind speed measurements from radiometers and altimeters.***
- ***ocean topography measurements of close to the desired accuracy from altimeters in orbits that will be known to a satisfactory precision. There is reasonable back-up from altimeters of lower accuracy.***
- ***wave characteristics from active microwave instruments (SAR and altimeters);***
- ***biological productivity estimates in the form of ocean colour measurements - the critical problems here are likely to be those of interpretation.***
- ***ecosystem monitoring using very high resolution visible imagery.***
- ***sea ice cover using SAR and radiometers at medium resolution.***

Therefore the period to 2005 is one in which the main challenge will be to demonstrate the value of this extensive provision of capable space borne instruments, in order to justify their continuation on an operational basis. It is essential that, as instrument suites are upgraded, there are adequate provisions for cross-calibration, and that these procedures are planned as a routine part of the operational system.

For planning purposes in the longer term and on the assumption that this demonstration is successful, it is to be expected that the GOOS will require access, on an operational basis, to missions that provide:

- ***SST data of the accuracy and resolution that are expected from AATSR, AVHRR/3, and MODIS;***
- ***Wind data of the quality expected of ASCAT and Sea Winds;***
- ***Ocean topography data of the quality expected of Jason;***
- ***Ocean wave data of the kind expected from the next generation of altimeters and SAR instruments;***
- ***Ocean biology data of the quality emerging from SeaWiFS and promised from GLI and MODIS;***
- ***Ecosystem information from high resolution imagers of the SPOT and LANDSAT class;***
- ***Sea ice data of the quality provided by SAR instruments;***
- ***continuation of INMARSAT and Service Argos, augmented by the next generation of communication satellite programmes such as Iridium;***
- ***continuation of the GPS/GLONASS navigation service .***

3.6.2 The Integrated Global Ocean Services System (IGOSS) and International Oceanographic Data and Information Exchange (IODE)

Although the IGOSS is sponsored by WMO and IOC and the IODE is an IOC programme, there is increasing co-operation between them and together they represent an important precursor of the GOOS.

The three components of IGOSS are:

- the IGOSS Observing System (IOS), comprising platforms and their observing systems. The primary sampled variables are SST, SSS, sub-surface temperature, salinity profiles and currents. Use is made of fixed and drifting buoys and the Ships of Opportunity (SOOP), deploying XBTs and XCTDs, makes an important contribution along the major shipping routes.
- the IGOSS Telecommunication Arrangement (ITA) that arranges for data to be transmitted in near real-time through a coastal radio station or satellite ground station to an NOC or NMC for quality control and subsequent input to the GTS.
- the IGOSS Data Processing and Services System (IDPSS) has the goal of integrating IGOSS data capture, communication and processing to generate the products required by end-users. The Global Temperature and Salinity Profile Programme (GTSPP) is one manifestation of this system, operated in conjunction with the IODE. The programme maintains a comprehensive data base of quality controlled, real-time and historic ocean temperature and salinity measurements, and distributes products based upon them. Although the IGOSS is sponsored by WMO and IOC and the IODE is an IOC programme, there is increasing co-operation between them and together they represent an important precursor of the GOOS.

The IODE system was established in 1961 to enhance marine research, exploration, and development by facilitating the exchange of oceanographic data and information between participating Member States. IODE is comprised of a hierarchy of centres from over 60 Member States including:

a. Designated National Agencies (DNA) that assist with the coordination of data exchange within the international community,

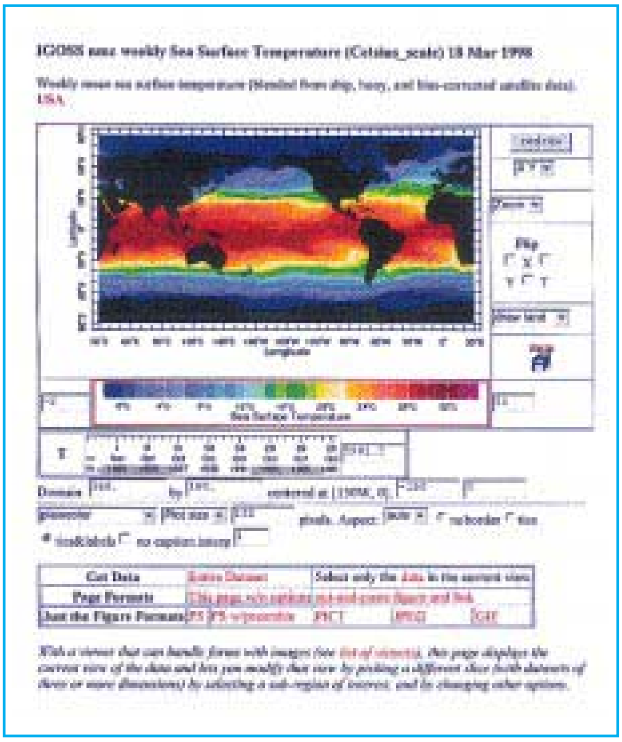
b. National Oceanographic Data Centres (NODC) have the resources to manage national data bases and provide data and information services to meet their countries requirements, they provide the contact with the oceanographic prgrammes in a Member State and from those programmes compile the data and make it available for exchange, and

c. Responsible National Oceanographic Data Centres (RNODC) that focus on specific data types or regions as well as supporting their national functions.

This structure provides data management support for the WDC system, particularly the WDC system for oceanography.

IODE operates a number of programmes and projects, including OceanPC (a set of customised software packages for ocean data processing and display), the Global Ocean Data Archaeology and Rescue (GODAR) project, Marine Information Management (MIM) and, as indicated above, GTSPP. Important areas of activity include the development of data exchange formats, quality control standards and procedures, technology exchange and capacity building. A range of products are provided to the user community.

There has been a clear and welcome commitment from IGOSS and IODE to jointly adapt to meet, inter alia, the needs of GOOS (IOC, 1996a). Their combined capability is clearly in line with the generic design of the GOOS, with near real-time delivery of level II and III products from IGOSS and delayed mode level IIB and IIIB from IODE. Neither programme contains a numerical modelling capability however. IGOSS/IODE recognise the challenge of achieving a satisfactory balance between meeting the needs of individual customers with the achievement of economies of scale that follow from the multiple use of data. They also accept that the number of data types must expand, and include remotely sensed data, if they are to meet the GOOS requirements.

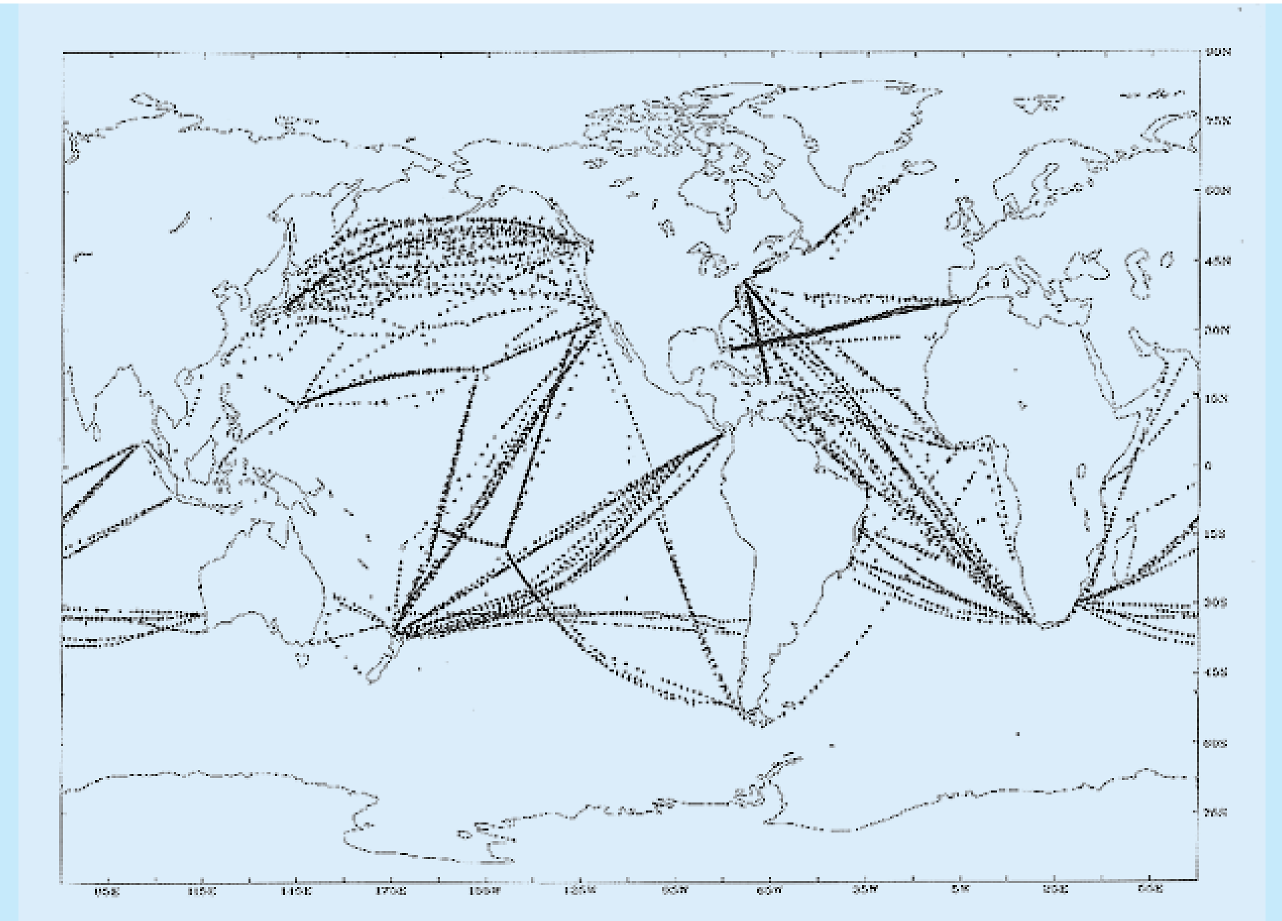


The operational base

A practical example of a prototype GOOS service is being provided by the combination of SOOP and GTSPP. IGOSS has helped to move the research-based Global XBT network and the SOOP to an operational status. A SOOP Implementation Panel (SOOPIP) has been formed to oversee implementation of the field programme and associated data flow. It obtains scientific guidance from the OOPC. With the assistance of an IGOSS Operations co-ordinator, a resource survey has been conducted and will be maintained. Deficiencies have been identified and prioritised. The IP monitors technical developments of interest to the Programme, such as ALACE/PALACE technology. It is supported by a Task Team on instrumentation and quality control that has organized inter-comparisons between various measurement techniques and maintains a watching brief on the adequacy of code forms in use.

The observing programme is limited by the location of the major shipping routes but currently aspires to populate the low density WOCE network. In 1996, approximately 100 dedicated Ships of Opportunity, operated by 7 IOC members generated an estimated total of 48,560 unique BATHY messages from XBTs and 2,585 TESAC messages were captured with CTD instruments. Nevertheless this represents only 61% of the number of XBTs required to complete the network of soundings.

Manuals produced by IGOSS recommend data quality assessment practices both before and after the data are exchanged. A GTSPP centre tracks the timeliness of delivery of data to users. Processed data, following removal of duplicates and including a data quality assessment, are distributed to users within 2 days of reception as well as at longer time scales. The centre has participated in a special monitoring exercise recently set up by WMO to confirm proper transfer of data on the GTS. Data quality is monitored by GTSPP monthly and a report is issued to data collectors detailing problems seen - this is an important function if the credibility of the products is to be increased and maintained. Examples of some of the products created using data sent through IGOSS can be found in the IGOSS Products Bulletin at: http://rainbow.ldeo.columbia.edu. An example is shown on page 58.



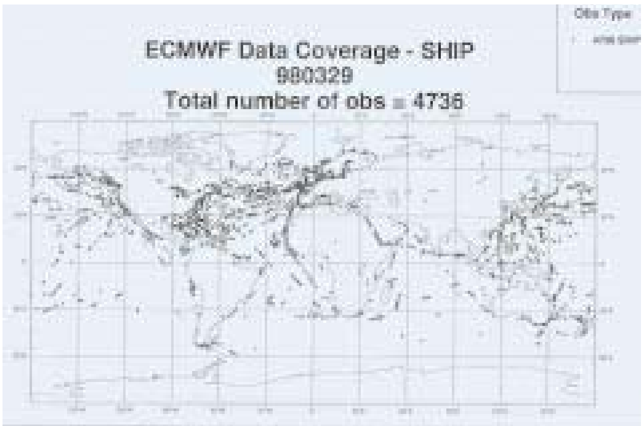
Global XBT distribution
January - August 1997

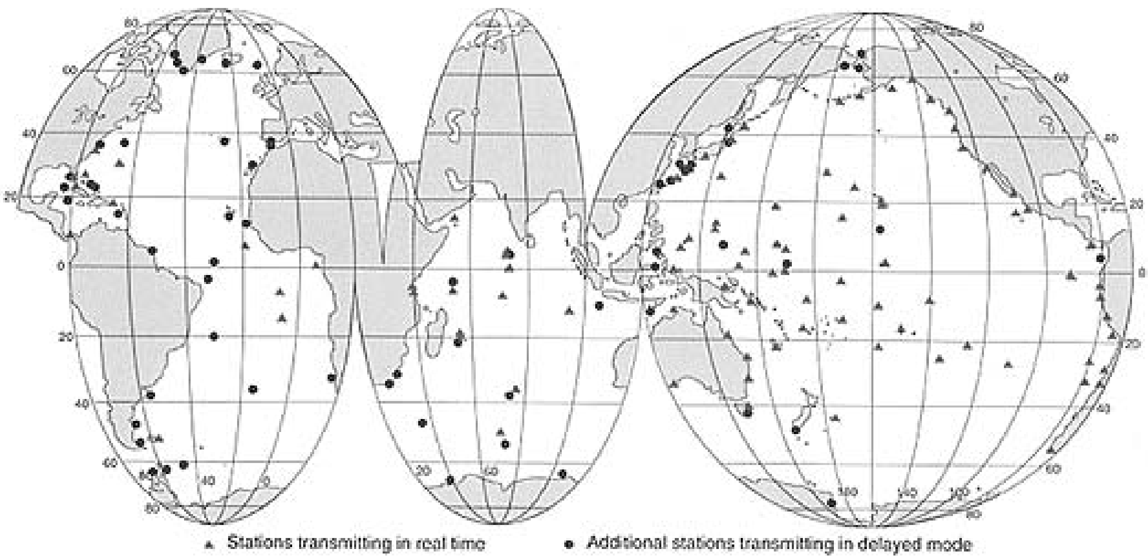
3.6
FOUNDATIONS OF THE GOOS

The operational base

3.6.3 WMO Voluntary Observing Ships Scheme

A fleet of some 7000 Voluntary Observing Ships (VOS) makes a significant contribution to the GOOS in the form of marine meteorological and surface oceanographic observations. About 40% of the fleet is at sea at any time making the necessary measurements, manually and automatically, at 6-hourly intervals. Data are communicated, primarily via the International Maritime Satellite System (INMARSAT), in real-time and in delayed mode by the collection of logbooks. Ships are recruited by some 50 WMO Members and co-ordinated by its Commission for Marine Meteorology. Members also operate an international network of ~ 200 Port Meteorological Officers (PMO), to commission and decommission equipment, collect logbooks and provide training and feedback to improve the quality of data. In some countries the PMOs perform a similar task in support of the SOOP (3.6.2). Lead centres monitor the performance of the real-time data stream.





Sea level stations

3.6.4 The Global Sea Level Observing System (GLOSS)

GLOSS was established by the IOC in 1985 as a network of tide gauges and associated infrastructure to monitor global sea levels, and also to help to develop national capabilities. The first GLOSS Implementation Plan, published in 1990, called for the establishment of a network of approximately 300 tide gauge stations distributed along continental coastlines and throughout each of the world's island groups, including the polar regions.

However, since 1990, several major technical developments have taken place most notably in the ability of satellite radar altimetry (ERS-1 and -2, TOPEX/Poseidon) to provide reliable and routine measurements of near-global sea level changes. Although the inference of ocean currents is dependent upon sea-level gradients, for maximum absolute accuracy the measurement of sea level change requires detailed knowledge of the geoid and/or cross calibration through other earth referenced systems such as the sea-level gauge network.

In response to these developments, a new GLOSS Implementation Plan (IOC,1997b) has been prepared. It provides a complete re-assessment, rather than an update of requirements for GLOSS, together with specifications for each component of the system. The specific elements of the GLOSS now include:

i a global tide gauge core network of some 200 – 250 sites;
ii. the recognition of the special importance of sites, hitherto in GLOSS or not, with long historical records suitable for the detection of long term sea level trends and accelerations;
iii. a calibration system for radar altimetry based on a subset of the gauges in (i);
iv. a further subset of the gauges in (i) suitable for monitoring the global ocean circulation;
v. GPS monitoring of land levels at gauge sites;
vi. a programme of ongoing altimetric coverage of the global ocean;
vii. provision of modern methods of data acquisition and exchange;
viii. programmes of training, and
ix. programmes of research at regional and global level.

The GLOSS 97 Implementation Plan calls for gauge data collection with delays between 1 and 12 months. The most demanding of these targets arises from the requirement to support altimeter interpretation. Since 1933 the PSMSL, based at the Proudman Oceanographic Laboratory in the UK, has been responsible for the collection, publication, analysis and interpretation of sea level data from the global network of gauges. Much of the output is made available via the Internet. In addition there are WOCE fast and delayed mode information delivery centres based at the University of Hawaii Sea Level Center and the BODC respectively.

At present there is no official centre to parallel PSMSL's responsibilities for long term tide gauge data and products, with respect to altimeter data, but PODAAC and NOAA/NODC in the US and AVISO and CERSAT in France provide such data for scientific purposes.

There are a large number of existing regional programmes that use sea level data – typically for the calculation of tidal constants, flood and storm surge forecasting services. Such data also play an important part in the Tsunami warning service for the Pacific. Tide gauge data, satellite altimetry data, and the calculation of geostrophic currents and predictions of sea level changes are important inputs to many GOOS products and services.

3.6.5 The IOC Tsunami Warning System in the Pacific

The Tsunami Warning System in the Pacific (ITSU), established by the IOC in 1965, is a co-operative effort for tsunami mitigation involving Pacific Member States. The IOC and NOAA maintain an International Tsunami Information Centre (ITIC) in Honolulu, Hawaii. The ITIC works closely with the Pacific Tsunami Warning Centre (PTWC) in Ewa Beach, Hawaii, with other warning centres, with scientific bodies, and with emergency management organizations to help carry out the ITSU mission.

The PTWC, also maintained by NOAA, is the operational headquarters of the Tsunami Warning System. It co-operates with other regional and national centres in monitoring seismic and sea level data from around the Pacific in real- or near real- time. Large earthquakes in the Pacific Basin are detected by PTWC within a few minutes of their occurrence from seismic data. Based on the computed location, depth, and magnitude of the earthquake, a tsunami warning and watch may be issued by PTWC for a limited region surrounding the epicentre. Data from sea level gauges nearest the epicentre are then examined to determine the presence and size of the tsunami as the wavefront passes each instrument's respective position. The warning/watch region is then either expanded or cancelled by PTWC as appropriate. In the case of a large tsunami, the sea-level network will provide data needed by the warning system to track and evaluate the waves as they propagate across the entire Pacific Basin in less than a day. Data from sea level gauges are also used for post-tsunami analyses and research.

3.6
FOUNDATIONS OF THE GOOS

The operational base

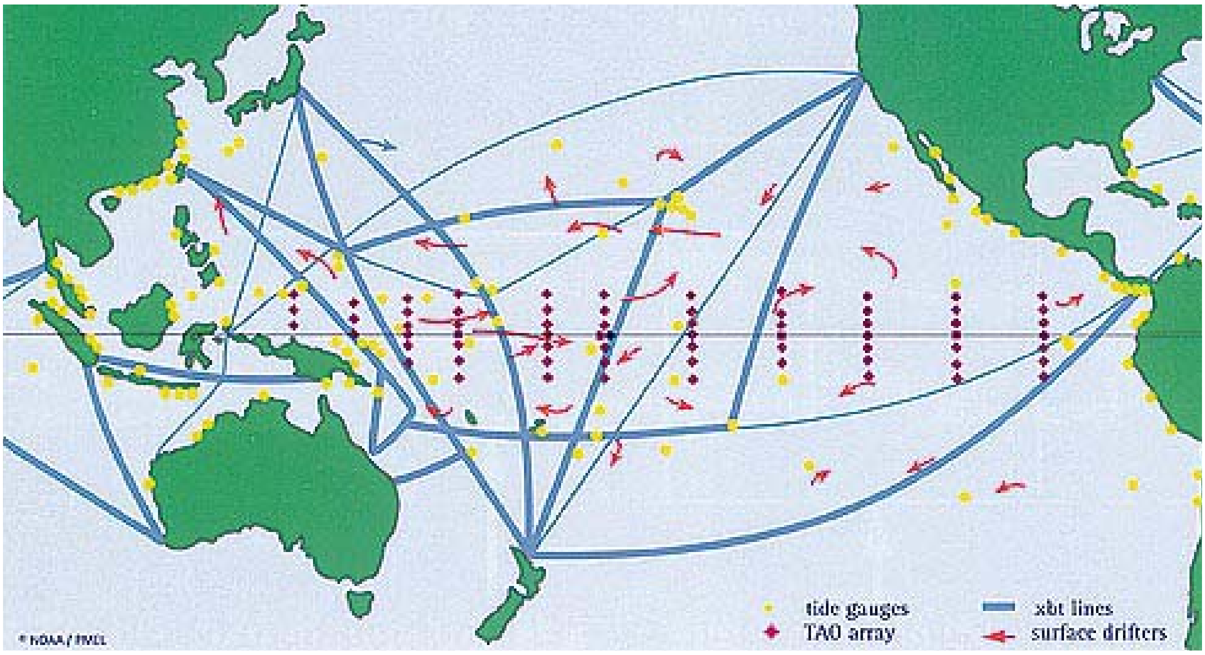
3.6.6 The TAO Array

The TAO Array consists of approximately 70 deep-ocean moorings spanning the equatorial Pacific Ocean between 5ºN and 8ºS from 95ºW to 137ºE.

It is a major component of the global climate monitoring system and is a committed component of the GOOS. It is supported by an international consortium, involving cooperation between the United States, France, Japan, Korea and Taiwan. It is managed by the TAO Implementation Panel, which is concerned with the development of observing systems in all tropical oceans.

The purpose of the array is to provide high quality, *in situ*, real-time data in the equatorial Pacific Ocean for short-term climate studies, most notably those relating to the ENSO phenomenon. TAO measurements consist primarily of surface winds, sea surface temperature, upper ocean temperature and currents, air temperature, and relative humidity. A subset of these data is placed on the GTS for distribution to operational centres for assimilation into weather and climate forecast models. A major step forward in long -term support for the array was the commissioning in FY96 of a vessel dedicated to servicing the TAO moorings between 95ºW and 165ºE. The next generation ATLAS moorings were also introduced into the array during 1996. JAMSTEC plans to begin deployment of TRITON buoys to the west of 165ºE from 1998, eventually into the Indian Ocean. These will increase the capability of the TAO Array, by carrying salinity sensors down to 750m, and extend monitoring of air sea interactions to those associated with the Asian monsoon.

The TAO project provides interactive access to TAO data, display software and graphics via the World Wide Web and workstation-based TAO Display Software. This is an excellent protoype for other GOOS activities.

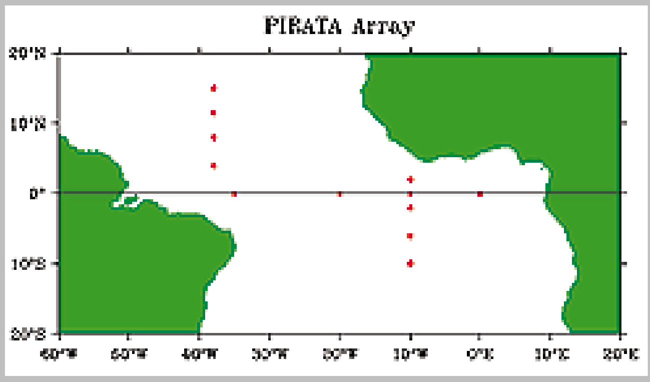


TAO array

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA)
PIRATA is an initiative put forward by a group of scientists from Brazil, France, and the USA involved in tropical climatic studies. The PIRATA program, that will be implemented as a collaborative multinational effort, proposes to install and maintain in the tropical Atlantic an array of 14 moored ATLAS buoys in the region 15°N-10OS, 0-35°W during the years 1997 to 2000. In addition to the ATLAS mooring array, wind measurements and tide-gauge data will be available in real-time from a number of small island sites and at least one coastal meteorological buoy.

PIRATA aims, inter alia, to:

- **provide an improved description of the seasonal-to-interannual variability in the upper ocean and at the air-sea interface in the tropical Atlantic.**
- **improve understanding of the relative contributions of the different components of the surface heat flux and ocean dynamics to the seasonal and interannual variability of SST within the tropical Atlantic basin.**
- **provide a data set that can be used to develop and improve predictive models of the coupled Atlantic climate system.**

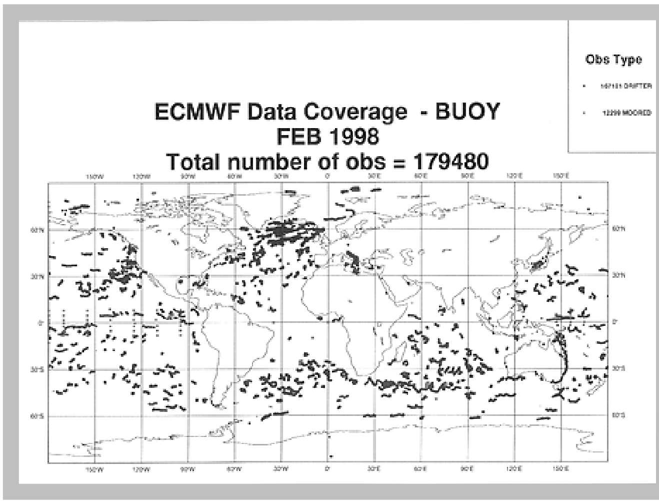


Three years of measurements will only barely touch on the issues of seasonal to interannual variations in the tropical Atlantic, and will not resolve decadal scale variability. But PIRATA has the potential to establish the foundation for a longer term monitoring network that will address more completely a broad range of problems associated with the variability of the tropical Atlantic.

3.6.7 Data Buoy Co-operation Panel (DBCP) Programmes

The DBCP was established in 1985 and its role expanded in 1993, jointly by the WMO and IOC.

The present global array of moored and drifting buoys is a blend of individual programmes serving a range of research and operational purposes, which are coordinated and integrated through the DBCP and its regional and global Action Groups. The DBCP also plays an important role, with a number of PMOCs, in the quality control of buoy data on the GTS.



In early April 1997 data from a total of 1222 drifting buoys operated by 19 countries were collected and processed through the Argos processing centres, in Toulouse, France and Landover, MA, USA (IOC,1997a). Slightly more than half of these transmit their data in real time over the GTS. Most measure at least SST and some 250 also measure air pressure. Annual reports (e.g. DBCP (1997)) provide a comprehensive account of the programme's activities and achievements.

The MEDS in Canada acts as the RNODC for drifting buoys. IGOSS/IOC and WWW/WMO provide a Regular Service Bulletin on non-drifting Ocean Data Acquisition Systems.

3.6.8 Global Coral Reef Monitoring Network (GCRMN)

Coral reefs are distributed throughout the tropical and sub-tropical waters of the world, mostly in developing countries. They support some of the highest levels of biological diversity in the marine environment and form an important basis for sustainable development. Millions of people around the world depend on coral reefs for their food and livelihood, particularly subsistence communities.

Unfortunately the health of coral reefs is in serious decline. Although only based upon a small sample, some estimates suggest that about 10% of coral reefs are already seriously degraded, many beyond recovery, and another 30% are likely to decline further within the next 20 years (IOC,1997c). As yet, there is no consensus on the extent and cause of the decline (Pennisi, 1997) but there is agreement on the need to gather data systematically. The GCRMN was set up for this purpose.

The GCRMN is cosponsored by IOC, UNEP and IUCN. They, together with the ICRI Secretariat and GCRMN joint hosts, AIMS and ICLARM, form a GCRMN Management Group. A co-ordinator has been appointed.

The goals of the GCRMN are to:

- improve the conservation, management and sustainable use of coral reefs and related coastal ecosystems by providing data and information on the trends in biophysical status and social, cultural and economic values of these ecosystems; and
- provide individuals, organisations and governments with the capacity to assess the resources of coral reefs and related ecosystems and collaborate within a global network to document and disseminate data and information on their status and trends.

A Strategic Plan (IOC, 1997c) has been prepared and a Methods Manual is being printed, following achievement of a consensus on monitoring methods and protocols. ICLARM is to operate a database that will enable the preparation of annual summaries of reef status. A pilot project to assess a series of reefs was set up in 1996. The collection of data and information on reef status and trends began in 1997. Three regional nodes, based on the UNEP Regional Seas Programme Secretariats have been created to implement the fieldwork and training called for by the Plan; others depend upon the availability of funding.

3.6.9 Global Investigations of Pollution in the Marine Environment

GIPME, as jointly sponsored by the IOC, UNEP and IMO, has two major objectives. These are: 1) To provide assessments of the state of the marine environment; and 2) To provide data and information, inter alia, to satisfy the requirements of the GOOS. However, GIPME has an additional responsibility to develop improved understanding of the processes involving the sources, transport, behaviour, fate and effects of contaminants in the marine environment. Such improved understanding will also provide benefits in improving the reliability of assessments and the modelling of GOOS data.

It is considered by the HOTO Panel that the experience of GIPME in regional monitoring activities places it in a unique position to deliver the regional assessments to GESAMP for its periodic reviews of the “State of the Marine Environment” at the request of its sponsoring UN Organizations, along the lines defined by GESAMP for Regional Marine Assessments (GESAMP, 1994).

GIPME includes work not specifically directed at regional issues, such as the development of methods for widespread application, preparation of reference materials and all projects addressing open ocean issues. Training workshops and intercomparison exercises are convened in the various regions to promote their monitoring effectiveness. The level of activity varies among regions.

3.6.10 The Marine Pollution Monitoring System

The Marine Pollution Monitoring System (MARPOLMON) of GIPME is the combined assembly of regional operational data gathering activities for selected contaminants in the marine environment. It is intended to provide one contribution to the HOTO module of GOOS through the delivery of data on conditions in the marine environment relating primarily to chemical characteristics, fluxes and their effects.

3.6.11 International Mussel Watch Program

The IOC/UNEP-GIPME International Mussel Watch Project, being carried out by the IOC in collaboration with UNEP, is an existing program that can be considered a prototype of continuing efforts needed internationally to monitor the health of the ocean (IOC,1996b). Begun in 1991 in collaboration with U.S. NOAA, this project included the collection of bivalve samples in Central and South America to quantify the sources and rates of input of wastes in that region. With the collection of samples and subsequent analyses by the participating laboratories, a data base was created for identifying trends. Approximately 300 samples from 80 coastal sites on both east and west coasts of the region were analysed at two referee laboratories, the Geochemical and Environmental Research Group at Texas A&M University, College Station, Texas, U.S., and MESL in Monaco, as well as at national laboratories in the participating countries. Additional tissue samples are available for further in-country analysis and inter-laboratory comparison. The project complemented a U.S. NOAA Mussel Watch Program begun in 1984 to monitor the North American coastline, as a follow-on to a prototype program initiated by the U.S. EPA in 1976. Further samples were collected and provided by Canadian participants. In addition to generating high quality data on chlorinated hydrocarbon, PCB and PAH concentrations and a quasi-synoptic baseline of the contamination in this global area, the International Mussel Watch Project serves as a field test for a global chemical contaminant monitoring program, as required by HOTO.

A Mussel Watch project is being implemented in the Black Sea and others are under consideration amongst Pacific Rim countries and in the Mediterranean.

The International Mussel Watch Project does not, as yet, provide data on the health of the biota, but only on the spatial distributions of contaminant residues. If such programmes are to effectively provide a framework for monitoring the health of the oceans, then in the future they must include indices of biological effects, such as histopathology. This will give an effective measure of the well-being of the mussels that can then be correlated with the contaminant distribution patterns. In addition, Mussel Watch could serve as a means of detection of the presence of human pathogens.

The operational base

3.6.12 The Harmful Algal Bloom Programme

The Harmful Algal Bloom (HAB) Programme was established in 1992 and has developed into an important activity of IOC. The Intergovernmental Panel on Harmful Algal Bloom (IPHAB) meets every two years to decide upon priorities for the programme and to review ongoing and already implemented activities. The HAB Programme Office is located in the IOC HQ in Paris. Additionally two IOC Science and Communication Centres on Harmful Algae have been established in Copenhagen, Denmark and Vigo, Spain. Regional groups in the Western Pacific, in South America and in the Caribbean and adjacent region have been established to coordinate regional efforts related to HABs.

The HAB Programme is designed to foster the effective management of, and scientific research on, harmful algal blooms in order to understand their causes, predict their occurrences, and mitigate their effect. The programme consists of three major elements: the educational element, the scientific element and the operational elements.

One of the major achievements of the programme is a very comprehensive training and capacity building programme. More than 25 training courses have been held in cooperation with other organizations and more than 300 people have been trained in biology, taxonomy, toxin chemistry and monitoring and management of harmful algae. A significant number of publications have been delivered including a 500 page manual on harmful marine microalgae, and a quarterly newsletter is published as well as other relevant bibliographic material. Currently the HAB Programme is actively participating in a working group on the dynamics of harmful algal blooms and a study group on ballast water and sediments.

Management and mitigation issues have been addressed by a global survey of HAB monitoring systems. All data are being worked into a database to be presented on the Internet. A workshop on the issue is planned. An international science agenda on the ecology and oceanography of harmful algal bloom is planned and will most likely be developed during the 1998 and 1999.

Harmful algae can poison fish and shellfish, and lead to human deaths and disabilities. Increased incidences of fish kills and fish with lesions in tributaries to Chesapeake Bay recently have led to considerable concern in the USA over the impact of outbreaks of toxic Pfiesteria piscicida and other harmful algal blooms. There is also evidence that outbreaks and spreads of shellfish algae harmful to people are related to seasonal-to-interannual climate variations such as ENSO.

3.6.13 Continuous Plankton Survey

At the Eighteenth Session of the IOC Assembly in 1995, it was decided to continue suport of the Continuous Plankton Recorder (CPR) Survey of Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in Plymouth, United Kingdom. The IOC supported the CPR activities with a contract for the biennium 95/96. The survey concerns the monitoring of living resources with the aim of a better understanding of their dynamics and sustainable use. The Survey, which in the North Atlantic has been carried out since 1946, also addresses questions on the influence of climate on long term changes in the abundance and composition of phytoplankton and zooplankton and the related changes in fish stocks.

The CPR activities are now, through the work of SAHFOS, being applied to more and more areas by the use of commercial ships of opportunity. The development of Large Marine Ecosystems (LME) in the Gulf of Guinea has been closely associated with the activities of the SAHFOS and the Continuous Plankton Recorder (CPR) has been used in the Region in the development of new routes.

The 'GLOBEC-IOC-SAHFOS-MBA workshop on the analysis of time series with particular reference to the Continuous Plankton Recorder Survey' has been published (IOC Workshop Report No.124). The papers submitted at the Workshop are inclosed in the Report.

The Survey, since it has been operational for a long time, provides a considerable experience in operational aspects, data handling, analyses and presentation of results.

3.6.14 The Regional Seas Programmes

Initiated and supported by UNEP in 1974, these programmes exist to enable the protection and management of specific marine regions and their adjacent coastal areas. Each programme addresses relevant global issues and activities. They are based on regional Action Plans, that have environmental assessment and management components. In most cases the plans are set in legally binding conventions agreed at intergovernmental level. Plan priorities are focused upon sustainable management of environmental resources and the development of response measures against the predicted impact of climate change. Some 14 regions are covered by the Programmes currently, involving more than 140 countries and some 400 national institutions.

The programme was under the overall coordination of the Oceans and Coastal Areas Program Activity Center (OCA/PAC) of UNEP and is now under the WATER branch. Because UNEP is a co-sponsor of GIPME, the marine pollution programs of the IOC and UNEP are closely coordinated.

3.6.15 Naval Operational Oceanographic Services

The USN, in particular, has implemented an excellent, practical example of the design outlined in chapter 4, targeted upon its own particular needs. The resulting programme has both operational and research components, with the latter being carried out to improve the former. Many data are captured by naval vessels. The USN's geodetic Earth observing satellite, GEOSAT, carried an altimeter capable of detecting and characterising variations in sea-surface height. Models have been designed specifically to deliver the products and services required by the Navy, by making maximum use of the satellite and *in-situ* data available to it, from its own resources and through international exchange. Because most of its operations are concentrated in the lower atmosphere and upper ocean and because of the strong interactions between these domains, much emphasis has been placed upon monitoring there and coupled ocean-atmosphere modelling.

Operational modelling is based at the Fleet Numerical Oceanography Center (FNOC), Monterey, California. Ocean models fall into three general categories, focused on particular service needs, (Clancy and Sadler, 1992):

- thermal structure and circulation models to characterise and predict ocean fronts and eddies, required for input to acoustic models. They also provide the SST boundary conditions for their NWP models and predict surface currents for search and rescue and optimum-track ship routing.
- sea-ice models in support of USN arctic operations.
- sea-state models to predict directional wave-energy spectra, again in support of ship routing and allied operations.

Emphasis is placed on using ocean models to convert well-observed surface oceanographic or atmospheric information into an accurate analytical representations of oceanographic fields for which observations are sparse or non-existent. For example, the surface positions of fronts and eddies observed by satellites are used to map subsurface salinity and thermal structure via synthetic data and ocean-feature models in the Optimum Thermal Interpolation System (OTIS) analysis (Cummings and Ignaszewski, 1991). OTIS assimilates all available real-time data via the optimum interpolation technique. The daily accumulation of such data consists of about 200 fixed and drifting buoy reports, 250 bathythermograph reports, 3000 ship SST reports and 120,000 multi-channel SST reports derived from the NOAA polar-orbiting satellites. In addition, a real-time 'ocean bogus' data-base, describing the surface positions of fronts and eddies, is produced by subjective interpretation of IR imagery 3-4 times per week.

Surface wind stresses and heat fluxes provided by the FNOC atmospheric models are used to predict mixed-layer depth and surface currents via parameterizations in the Thermodynamic Ocean Prediction System (TOPS) model (Clancy and Pollack, 1983). TOPS is a synoptic mixed-layer model that consists of conservation equations for temperature, salinity and momentum in the upper 400m of the ocean. Initial conditions are provided by OTIS.

3.6 FOUNDATIONS OF THE GOOS

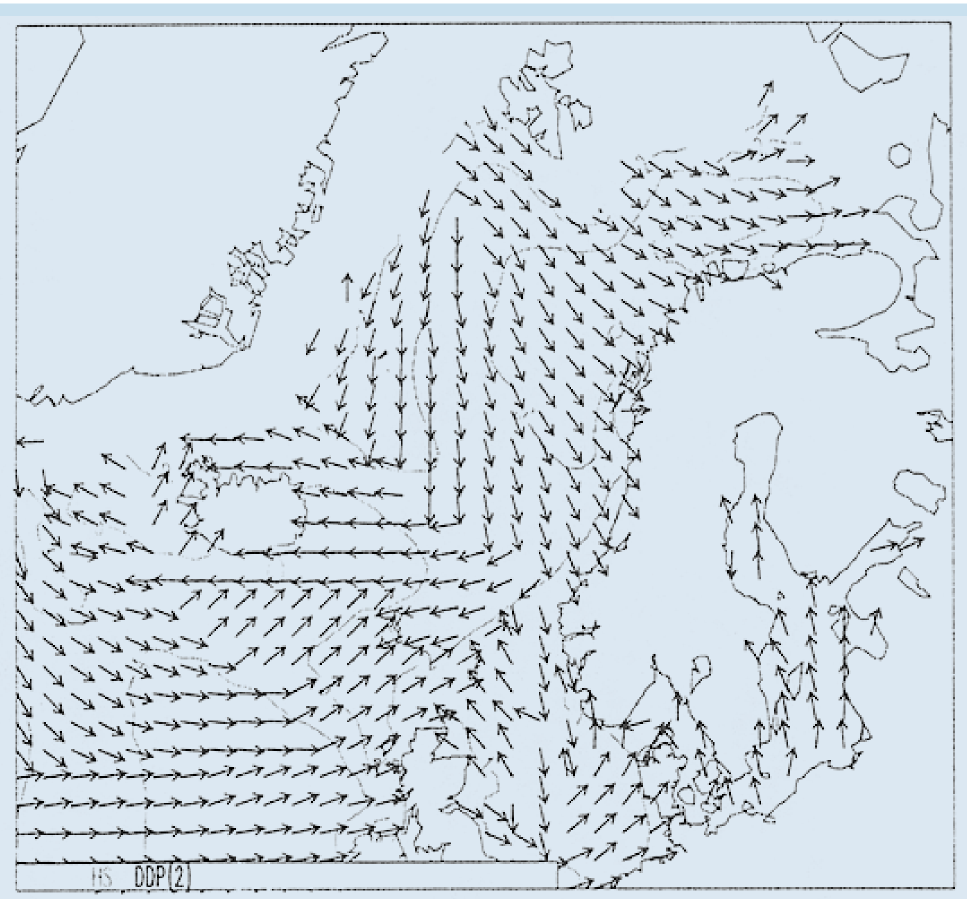
The operational base

Global scale OTIS/TOPS products are typically represented on a 1.25° grid from models run on separate hemispheric polar stereographic grids, with resolutions varying from 100 km to 180 km. Before having the resources needed for eddy-resolving global and basin scale predictions of ocean circulation, developmental effort has been focused on eddy-resolving models of small domains and non eddy-resolving global models, and on issues and techniques related to assimilation of satellite altimeter and IR imagery data (Hurlbert et al, 1992). For example, the U.S. Navy Research Laboratory is operating layered models of the Pacific north of 20°S with a spatial resolution of 1/16° and 1/32° (Moore and Wallcraft, 1996).

In recent years there has been a steady convergence of navy and civilian services, with the creation of a joint NOAA/Navy Upper Ocean Operations Centre.

The UK Meteorological Office has developed and is running operationally a 1° resolution global ocean model, called FOAM, for the Royal Navy. This Forecasting Ocean-Atmosphere Model assimilates SST and XBT data and is forced by atmospheric fluxes from the Meteorological Office NWP model (Foreman et al, 1996). Output products comprise analyses and 5-day forecasts of upper level temperature, salinity, sea-ice concentration and thickness, mixed layer depth and currents. There are plans to assimilate altimeter data and to introduce higher resolution regional versions of the model.

A quasi-geostrophic open ocean model (SOAP) of part of the Eastern Atlantic has been developed and used in pre-operational trials to provide services for the French Navy (Dombrowsky and De Mey, 1992). The model assimilates ERS and TOPEX/Poseidon data using optimal interpolation techniques. The experience is assisting development of the SOPRANE model of the north-east Atlantic, that is due for delivery in 1998, will be quasi-geostrophic and have 1/10° horizontal resolution.



WINCH wave model (75km grid), showing significant wave height and direction.

3.6.16 Conclusions and implications for the GOOS

The foregoing demonstrates that, in addition to the Space Programmes described in section 3.6.1, there have been for some time a number of operational activities in place and delivering services akin to those that are expected of a GOOS (see chapter 4). Many of these existing systems have now been included in the GOOS Initial Observing System (GOOS-IOS) described in chapter 5. In all of the examples described above lessons have been or can be learned for the design and implementation of the GOOS. In several cases the nature of the existing programmes is so close to that of the GOOS that economies of scale are likely if they commit in part or as a whole to the GOOS, as some have already done (Chapter 5).

Thus, the Regional Seas Programmes, GIPME/ MARPOLMON and the Mussel Watch projects are directly relevant to the needs of the HOTO module (4.5.3).Data collection within the GCRMN is likely to be very useful for wider GOOS purposes. There is some concern that occurrences of harmful algal blooms are increasing worldwide, though this may possibly reflect increasing observation. Clearly monitoring the occurrence and development of such blooms, and modeling their potential trajectory will be of value to human consumers and the fish and shellfish producing industries, as will forecasting the conditions that lead to outbreaks. There is evidence that such blooms may be stimulated by runoff of excess nutrients from land fertilization, which connects the need to monitor pollution by nutrients to the need to monitor bloom production.

The IGOSS/IODE and their initiatives in the form of the SOOP and GTSPP, the DBCP and VOS, the TAO array and its extensions are providing and processing physical data in a manner that suggests that they can make a substantial contribution to the GOOS. Naval data collection and processing provide important experience for real-time GOOS activities and it may be possible for some naval data to be accessed, in delayed mode at least, for wider purposes.

Other existing services, usually at local or regional seas scale, provide essential experience in the necessary engineering and operational skills of 24hr, 365 days per year data gathering, data transmission, modelling, forecasting and product delivery. These include floating sea ice prediction, wind wave and current forecasting adjacent to harbour entrances, and around oil platforms, and storm surge detection and warning systems. The existing fisheries stock assessment system is also a precursor of potential GOOS services which could provide predictions of the lower trophic levels. The GOOS has the potential to develop and build upon the experience and best practice of these dozens of observing systems, almost all seriously limited in space and time, and through improved observational strategy, combined with nested models, generate improved services at every scale from global to local.

4
THE DESIGN OF THE GLOBAL OCEAN OBSERVING SYSTEM

Chapter 1 has described the vision, aims and objectives of the GOOS and established the design principles for the system that will achieve them. Chapter 2 has outlined the essential guidance of the Strategic Plan. This chapter explains how these ideas are to be applied in practice and outlines the essential features of the resulting end-to-end system(s) that are required. Section 4.2 outlines the processing chain(s) that are necessary and section 4.3 describes the principles of data and information management to be employed. The emphasis, at this stage, is upon the functional performance of subsystems rather than their location and detailed attributes.

The particular intellectual and material foundations upon which the GOOS is to be built are described in Chapter 3. The importance of an enabling legal and organisational structure has been emphasised. A number of GOOS Panels have been set up within specific sectors or Modules and have begun that construction by identifying user needs andscientific/technical priorities. Their conclusions and recommendations are reviewed and consolidated. They allow tentative design conclusions to be drawn. These are built upon in the proposals of chapter 5, and then tested in some illustrative prototype and pre-operational services described in chapter 6.

The value-adding process

4.2 The scientific design of the GOOS

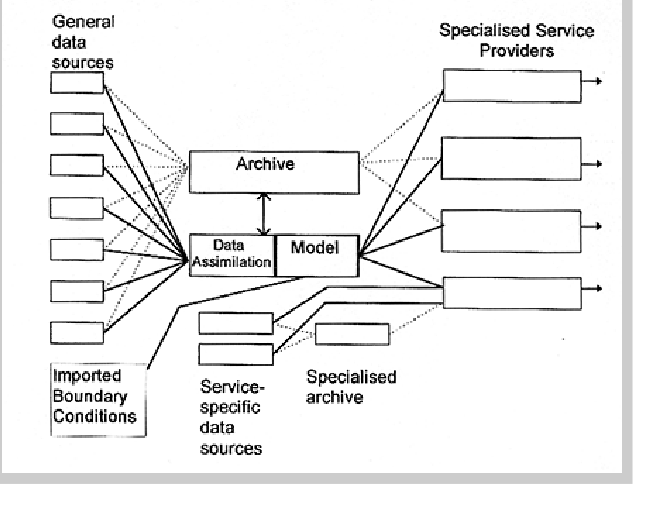
The productive design of the GOOS, as opposed to opportunistic linking together of existing operational services, presupposes an excellent scientific basis of knowledge which can be used to specify the time and space scales of observations needed for each process and variable to be predicted. On the principle that the GOOS should, so far as possible, be based on existing systems, and existing global ocean science experiments, Section 3.4 has described very briefly the large scale ocean science and marine biogeochemical experiments underway at present. These are more fully described in Annexe 3. Each of these experiments has produced, or will produce, knowledge of ocean processes and phenomena such as the North Atlantic Oscillation (NOA), the Atlantic thermohaline circulation, or the global carbon cycle, which will be essential for designing the optimum sampling strategy for parts of the GOOS. Already the preliminary studies of the GOOS Module Panels, and of NEAR-GOOS and Euro-GOOS have identified areas of research which are specifically needed to solve problems which are delaying the implementation of the GOOS. That is to say, the process of starting to design the GOOS itself reveals further research which needs to be done. As the GOOS develops and becomes more effective in terms of economic and social benefits, further research will be justified to continuously improve the design and operation of the system.

4.3 The value-adding process for environmental information services

The figure below shows the generic process by which value is added to data about the environment in a large number of advisory services. It is as applicable to operational oceanography as to operational meteorology.

The essential features are:

- The multiplicity of data sources that are required to provide a given service; some of these are likely to be from disciplines other than environmental observation – a GIS for example. Some data sources will be used for several services; others will be service-specific.
- The dual process of archiving, to generate a historical data base, typically used for design purposes, and of modelling to generate prognoses. Almost all practical advisory services have a need for these two components at some stage, although specific products may be derived from one or the other. An assessment of the marine environment or a climatology would be produced solely from the historical data base, for example – although see the point below concerning the use of hind-casts.
- The model may represent a very simple physical relationship, such as geostrophy, but in many cases it will consist of a numerical model representing many processes; in others a statistical or other form of empirical model may be employed.
- Boundary conditions have to be defined for the model. They can be state variables at the boundary and/or fluxes across it. They can be fixed or imported from a model with a larger or neighbouring domain. A coupled atmosphere-ocean model is a special case where there is a two-way exchange of boundary conditions. It is common for a model of high resolution but limited domain to obtain some of its boundary conditions from a similar model of lower resolution but covering a larger domain, within which the high resolution model is said to be 'nested'. It is normal for a model of the physical environment to be Eulerian (i.e. on a fixed grid) but increasingly Lagrangian (particle following) methods are used to model biological processes.
- A physically based numerical model also brings with it the powerful tool of data assimilation, with the capability to impose dynamical consistency and extract the maximum possible information from an observation. Adjoint models, developed for 4-D variational data assimilation purposes, are able to diagnose the sensitivity of short term predictions to input information, so have an important role to play in observing network design.
- Connectivity is required between the archive and model to allow the creation of hind-casts, that can be used to create climatologies of variables that have not been monitored from those that are in the archive.
- A wide range of functions can be and are carried out under the label of specialised services, including the accessing of model and archive output, further specific-to-purpose physical, chemical and biological modelling, interpretation of analytical, diagnostic and prognostic products, and the presentation to end-users to achieve the desired impact.
- In terms of the data category conventions of annex 4, the 'data sources' in the figure are at level II, whilst the 'Imported Boundary Conditions' are likely to be at level II or III. The 'Specialised Service ' modules will look to receive level IV data from the 'Model' and level IIB or IIIB from the 'Archive' functions.



Value-adding in an environmental information service provision

- A process of this kind requires effective quality assurance procedures. In general these include quality monitoring at key points in the chain and effective feedback of the results to earlier stages to advise corrective action. Thus, data assimilation provides a very effective way of detecting constant and time varying calibration errors and outliers in observations; service providers need the capability to verify the quality of prognoses if they are to make effective use of them.

The practical design of such a value-adding process will depend crucially for its effectiveness and efficiency upon the capability of the infrastructure, and the information technology (IT) in particular, that supports it. The availability of powerful parallel and/or vector processors on which to run numerical models is fundamental in this regard and a view has to be taken on this in the design. When the information being supplied to modelers or users is perishable, the capability of the installed communications is of significance too.

Finally, an operational process of the kind sketched in the figure has to have an active and closely coupled R&D programme, both to improve the quality of the resulting services in line with user expectations and to cope with the inevitable changes in inputs such as the supply of data, technology and scientific understanding.

4.4 Data and Information[3] management

The GOOS is able to take advantage of, but will need to build on, a number of past initiatives in managing data on a global scale for the purposes of providing environmental information to a wide range of users. These include the research community actively engaged in improving the quality of that information, the IGOSS and the IODE, described in paragraph 3.6.2, and the Data Management System of the WWW. The work of the GCOS Data and Information Panel (GCOS, 1995), whose terms of reference[4] have been modified recently to include GOOS and GTOS needs (GOOS, 1997) and its title changed to that of Joint Data and Information Management Panel (JDIMP), is relevant too. Such experience and expertise is valuable and what follows has been adapted from those sources.

To meet the requirements of all of its users, the GOOS and other members of the G3OS will need to provide for:

1. **all pertinent data and products to be identified and made available to those adding value**, or end users who can realise that value. This entails the sort of scientific insight and knowledge of user needs that are being provided by the Modules (4.5) and a data policy that facilitates exchange and access. To expedite identification and improve access to the required sources, specific actions to set up an Information Centre and a Data and Information Service are proposed in chapter 5.
2. **international communication networks and efficient, standard formats and codes to make best use of them.** Such networks and protocols must have bandwidth sufficient to allow straightforward timely interaction with data centres located almost anywhere in the world. They should, therefore, reach nearly all countries and be interconnected so information can pass freely between them.
3. **advanced quality control and validation systems.** These systems should ensure that the huge volumes of data required and collected are fit for purpose. Such systems need to be active, in the sense of generating feedback that can be used to correct defective processes.
4. **generation of high level products.** To realize the potential inherent in many environmental observations, data from different sources need to be processed and combined, as described above, to create high level products and advice.
5. **archival methods that retain the value of historical data.** This requires appropriate collection, maintenance and dissemination of documentation and metadata. This is particularly important when data holdings are expected to be of long duration and use will be interdisciplinary.
6. **an integrated international data base.** For users to locate and recover the information they require, the information should be described in and accessible from advanced data processing systems of the kind described in the figure. While these systems will be developed and maintained in a variety of locations, ideally they should be connected and operate in a coordinated manner so that information stored at different sites are as accessible as if stored in a single location. Although developed and operated independently, these systems should provide a standard set of access methods that allow the GOOS participants to investigate the availability of and order data or products to be delivered via a variety of means. For participants without on-line access, high-level information should be collected and distributed on inexpensive media. A schematic of the system envisioned is provided overleaf. The Data Centres shown will carry out one or more of the processing functions shown in figure opposite.
7. **advanced workstations.** With the huge increase in data volume that is anticipated within ten years, it will not be sufficient to present data as tables of numbers. Instead, nvestigators will need a comprehensive set of tools to manipulate, analyse and visualise data. These tools, that will include GIS, should minimise the effort required to load and convert data into a format that local software can read. Participating states and institutions will be encouraged to share and develop software with the needs of other GOOS participants in mind.

[3] Where it is necessary to be precise about the processing which data have undergone, the characterisation of annexe 4 will be used; more generally 'information' will apply to data at levels II, III and IV
[4] See annexe 2

4.4
DESIGN OF THE GOOS

Data and information management

It is envisaged that the JDIMP will have particular responsibility for generating and promoting advice relating to functions 2, 3, 5 and 6 whilst the Modules can be expected to provide guidance on 1 and 7, in particular by keeping abreast of new needs and of scientific and technical developments. The important task of identifying the centres able and willing to carry out functions 4 will fall to the GSC (see also chapter 5).

In order to meet these needs a strategy, compatible with and building on that outlined in chapter 2, with the following attributes will be pursued:

a **To the fullest extent possible, the GOOS data and information system will rely upon existing national and international programmes and be implemented in concert with the GCOS and GTOS.** Systems operated by programmes such as the ICSU World Data Centres, WWW, IGOSS and IODE will be enhanced as necessary to meet G3OS requirements. While the G3OS will oversee development of a coordinated information system design that identifies the responsibilities of all co-operating agencies and programmes, they will not create new institutions to carry out the tasks required for implementation, initially at least. Instead, these tasks will need to be performed by the existing world and national observing systems, telecommunications networks, and data and processing centres. The G3OS will act as catalysts to ensure data are collected, validated, and processed to the exacting standards necessary. The G3OS will promote new approaches to data processing that support interdisciplinary use of data. They will encourage routine production of assimilated analyses and model studies. They will advocate improvements in data access and distribution.

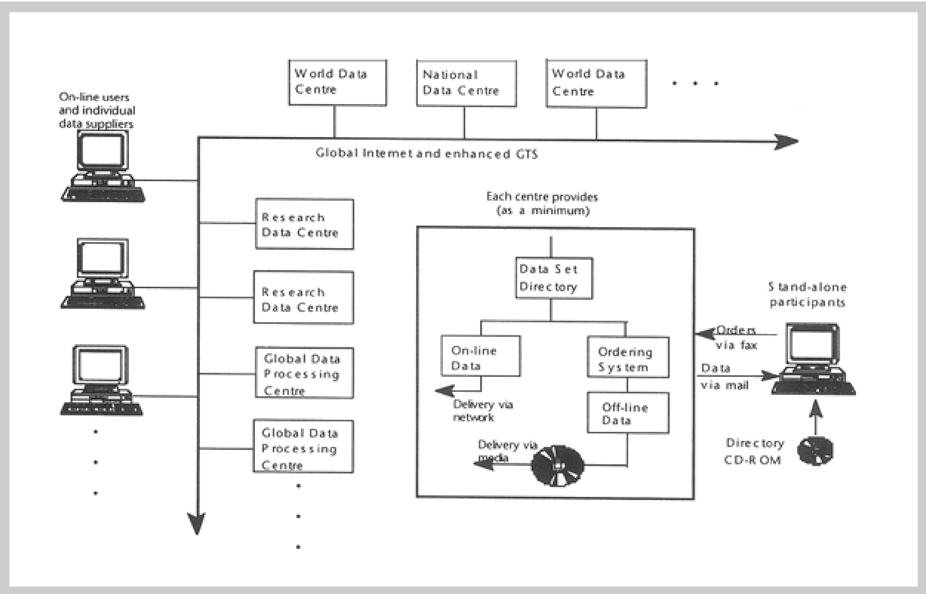
b **Maximum use will be made of international standards** that allow participants to read data more easily and encourage exchange of data processing and analysis software. To the extent possible, accepted international standards will be used for the acquisition, processing and distribution of G3OS information. Where additional standards are required, they will be developed in cooperation with appropriate national and international programmes. In the short term, emphasis will be on ensuring that data and products are available to participants in standard formats, on low cost media and through standard communications protocols. In the longer term, standards for automatic transmission of queries to and replies from data bases are desirable.

c **Information systems will be designed, monitored and evaluated to ensure fitness for purpose.** The functions described above, and as necessary to deliver specified benefits, will be carried out by competent organisations with appropriate long term commitments.

Quality assurance of scientific data is best achieved when the data are examined by those collecting the data and by users and researchers who have a personal, professional interest in the data. The primary role of the G3OS will be to:

- coordinate and oversee the development of guidelines for data quality;
- encourage utilization and implementation of the most appropriate quality control techniques for each data problem. This will include obtaining the agreement of operational centres to perform specific tasks in the quality control loop.
- act as a clearinghouse for information on these techniques and promote transfer of technology between environmental data and processing centres.

d **For providing access to information, maximum use will be made of modern technology that is in widespread use.** By using such 'consumer ' technology, costs are likely to be minimised, reliability and availability maximised, and it is wholly consistent with the intention to rely on distributed information systems. Training costs will be minimised and the participation of developing countries will be eased. In practice, this approach is likely to result in substantial reliance on client-server technology and the Internet.



A conceptual information access system

Practical design considerations

4.5.1 Key questions

Answers to a number of questions are required to design particular manifestations of the GOOS.
These include:

1. What information is required to satisfy particular economic, social and political needs?
2. Is it available? If not what can be done to obtain it?
3. What variables should be measured? With what accuracy and temporal and spatial resolution? Over what domains?
4. Is the technology available?
5. What models and data sets are available or might be created and developed?
6. Who will operate them?
7. What arrangements are necessary to build in the required quality assurance?
8. Can all this be justified, given the benefits that are to be realised?
9. How will funding be achieved?

4.5.2 General considerations

The answers to some of the above questions have natural constraints on them. Thus **the natural space and time scales** of variability set design criteria for observing systems, particularly for monitoring purposes, where the question of the representativeness of a measurement is crucial.

Infrared imagery of the ocean's surface shows spatial variability associated with the major surface currents. Some of this has scales of less than 100 km. Oceanic fronts have widths of 10-50 km. Eddies with scales of 10s of km down to 5 km can be associated with these fronts. This is to be understood by reference to the Rossby radius as a fundamental length scale of fluid flow on a rotating body such as the Earth. It is the scale at which rotational forces acting on the fluid motion become comparable to buoyancy forces. In the ocean, the equatorial Rossby radius is some 200 km; at mid latitudes it is around 30 km decreasing to less than 10 km in polar waters. The eddies are dynamically and energetically highly significant; horizontal turbulence is estimated to contain 99% of the kinetic energy of the oceans.

Isotopic and current meter measurements, the movement of ALACE floats and TOPEX/Poseidon data gathered during the field phase of WOCE, and high resolution modelling using tools such as FRAM and OCCAM, all point to great importance of bottom topography in controlling substantial intermediate and deep oceanic flows (Davis et al, 1996; etc). Relevant topographic variations have horizontal dimensions of a few km. In coastal zones sub-km resolutions are required to resolve variations induced by topography.

The tidal, diurnal and annual periods set a natural time scale for many events and care must be taken to either average over or resolve such periods, depending upon the purpose of the measurement or model. However, the flow also imposes a characteristic timescale that must be borne in mind. Thus the growth rate of unstable perturbations is a function of the horizontal and vertical structure of the flow and the vertical gradient of density. In regions of highly sheared flow, such as the western boundary currents, the development time scale is a few days. In the centre of the oceans, away from swift currents and fronts, eddies are long-lived, with time-scales of around 100 days. Nevertheless, there are features of the broad ocean circulation that are conserved over a period of years – an important proposition underpinning the design of the field phase of WOCE.

There will always be some scales that are not resolved but care must be taken not to alias high frequency variability into lower frequencies and thereby generate false signals. Interesting discussions of these matters are contained in GLOBEC (1993a) and OOSDP (1995).

4.5
DESIGN OF THE GOOS

Practical design considerations

Similar concerns dictate **the resolution of numerical models**. Ideally such models should fully resolve the essential processes that govern the evolution of the medium being modelled. Where this is not possible, the essential effects of the unresolved processes on those that are resolved, typically dynamical, must be parameterized. It is common experience that increasing computer power allows more processes to be modelled explicitly and the use of more sophisticated parameterization of the processes that cannot be resolved.

At present, global oceanographic models are being run routinely, for climate research and military purposes, with a horizontal resolution of ~1°. Eddy permitting (horizontal resolution ~ 30 km) models covering domains of the order of the major ocean basins have been evaluated in research programmes (e.g. FRAM) and operational use is almost feasible. Eddy resolving models (~5 to 10 km) for such domains should be feasible within a few years. Shelf models having a resolution of a few km and those with a domain of an estuary with a resolution of better than a km are state-of-the-art. For some purposes modelling of processes on isopycnals is preferred; for others, modelling on constant levels provides better results (Roberts et al, 1996 and Marsh et al, 1996).

Many coastal management problems affecting particular semi-enclosed seas, estuaries or bays will not justify nor require monitoring or modelling of the kind being envisaged within the GOOS. However, where there are many inputs of potential contaminants and complex flow regimes, a three dimensional dispersion model and a compatible long term monitoring programme are likely to be necessary. Typically, the model will have a horizontal resolution of one to a few km and sufficient levels in the vertical to represent the euphotic zone and exchanges through the upper and lower boundaries

It is worth emphasising that one of the strengths of the modelling approach is that it permits inference about variables at considerably higher temporal and spatial density than that of the data which are assimilated or used for verification.

In determining **the accuracy** with which a particular measurement must be made, some knowledge of the expected signal and noise amplitudes have to be available. Long term monitoring places particular demands in this respect where low frequency, low amplitude signals are likely to be buried in significant high frequency variations. Long term stability in the measurement methods becomes crucial. A check also needs to be run against the possibility of inferring a variable to the required accuracy by use of a (perhaps simple) model and a surrogate measurement.

As concerns the **domains or scope** of observations and modelling: It is inevitable that a user-driven design and prioritisation process emphasises local and regional perspectives; it is on those scales that benefits are experienced. The science invariably assists this localisation tendency, by pointing to sensitive processes and measurements and the physical ‘choke points’, where economy can be achieved by making measurements of the highest value – at least initially. Economy in the use of resources dictates that the modelled domain is the minimum necessary to achieve the stated objective. However, the requirement to extend the lead times of predictions invariably leads to a contrary pressure to increase the domain to internalise the processes that influence evolution over longer periods. The compromise in specific cases hinges on such matters and the ease of specifying and handling boundary conditions and forcing functions. Practical solutions are likely to be based on the use of **nested** and/or distinct but **coupled** models.

There are practices that common experience dictates are important design considerations for operational information services. These indicate that:

- alternative solutions to selected technical and scientific problems should be encouraged to provide resilience, to expose the sensitivity of results to particular assumptions and to encourage innovation (see the U.S. experience in section 6.2 for example).
- it is rarely cost-effective to maintain obsolete systems; new technology has the potential to improve efficiency and effectiveness. However, the use of new technology without concern for maintenance of continuity of the record is not acceptable.
- although empirical methods have a role to play, the quality of services depends on the degree of scientific understanding that underpins their production.
- data collection, transmission and processing should be conducted in as short a time as feasible (a commitment being made in the GODAE – section 6.7).

4.5.3 Specific considerations

In order to provide specific answers to the questions posed in paragraph 4.4.1 in relation to particular user needs and thereby enable practical design and implementation to proceed, five discipline-oriented Modules have been set up. These concern:

- Climate Monitoring, Assessment and Prediction
- Assessment and Prediction of the Health of the Ocean
- Monitoring and Assessment of Living MarineResources
- Coastal Seas Management and Development
- Marine Meteorological and Oceanographic Services.

Each of the Modules has a Panel and/or has conducted one or more workshops to consider such issues.
In particular, to determine what needs to be done and what is scientifically and technically feasible. Their specific Terms of Reference are at Annex 2.

Balancing user needs and scientific/technical feasibility

4.6.1

The Terms of Reference of the Panels and workshops require a wide ranging review of the needs of the major stakeholders, knowledge of the international framework within which actions are to be taken, and the science and technology available from which to devise solutions.

4.6.2 Climate monitoring, assessment and prediction

The need

The Second World Climate Conference 1990, in both the scientific and ministerial sessions, recognized the need for a systematic approach to be taken to obtain observations critically needed to answer significant questions about climate change and climate variability. The recommendation from the Conference called for the urgent establishment of GCOS to meet the needs for climate system monitoring, for climate change detection, for climate modelling and prediction, and to provide information for national economic development.

Linking economic and environmental concerns, the Agenda 21 Programme (3.1.6), explicitly recommended that nations contribute to the enhancement of scientific knowledge of climate by developing and expanding GCOS.

The IPCC assessments and the FCCC Conferences of the Parties have drawn heavily on available observations, the underlying science and modelling of climate, its forcing and of the impacts of change in order to reach a consensus on the control of greenhouse gas emissions. An August 1997 Conference on the WCRP has noted that there is a decline of conventional observation networks in some regions, putting at risk future assessments and reasoned action in this regard. It is important to note that these needs go beyond the monitoring of climate alone.

As discussed in section 6.2, skill in seasonal to interannual prediction has reached useful levels in some parts of the world. But again this is dependent upon the combination of observation of key variables and modelling.

The impact of climate on food production, water resources and sea level and the implications for sustainable development are discussed at length in Houghton et al (1996) and references therein. The significance of climate in the spread of infectious disease is noted in paragraph 1.3.2. Climate also affects life and health indirectly through its effects on supplies of fresh water and food, and on sanitation and housing. For instance, half a million people in Bangladesh died in coastal flooding induced by storm surges in the Bay of Bengal in November 1970. Famine induced by droughts weakens people making them more susceptible to disease. Dramatic climate changes in marginal areas create large populations of refugees, as in the Sahel, where drought is linked to fluctuations in sea surface temperature in the eastern Atlantic (6.2).

Planning within the context of the GOOS

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

An Ocean Observing System Development Panel (OOSDP) was established under the JSC of the WCRP and the IOC-SCOR Committee on Climatic Changes and the Ocean. It was given the task of formulating a “conceptual design of a long term, systematic observing system to monitor, describe and understand the physical and biogeochemical processes that determine ocean circulation and the effects of the ocean on seasonal to decadal climate changes and to provide the observations needed for climate predictions”. It reported in OOSDP (1995).

To provide a systematic means of prioritising observational elements and assessing the projected outcomes of the system design, the OOSDP selected a set of goals and subgoals that relate to the various physical aspects of the ocean and its role in climate. The 3 goals segment the scientific problem into:

1. surface fields and fluxes;
2. the upper ocean;
3. the interior ocean.

For each of these segments, specific measurements (subgoals) were identified which the Panel believed were sufficient and necessary, at the contemporary state of knowledge, to enable the task defined above to be carried out. These were prioritised by considering jointly their **impact** on the task, and the **feasibility** of making them to the quality required. The result was a set of ranked actions relating to the measurements required.

A summary of the existing operational elements and prioritised elements to be added to achieve the identified specific measurement or sub-goal. The sub-goals are ordered by priority assigned by the OOSDP.

4.6
DESIGN OF THE GOOS

Balancing user needs and scientific/technical feasibility

Specific Measurement		Priority	Elements of existing operational systems	Elements to be added to form the initial observing system
1a	SST, SSS	1	AVHRR VOS SST Moored and drifting buoy SST	1) ATSR 2) SST on improved VOS 3) SST on more drifters 4) SST &SSSon TAO array
1b	Wind and wind stress	1	VOS met observations NWP model analyses Buoy SLz	5) Scatterometer 6) TAO array winds 7) SLP in S. Hemisphere 8) Improvement of VOS winds
2b	ENSO prediction	1	operational analyses of SST and tide gauges	9) T(z) from VOS 10) T(z) from TAO array 11) V(z) from TAO array 12) precision altimeter
3c	Global sea level change gauges	1	nil	13) high quality geocentrically located tide
1c	Surface heat and water fluxes	2	operational analyses of SST and wind NWP surface fluxes Buoy and VOS met observations) surface radiation and precipitation from satellites	14) improved VOS met observations 15) *in situ* radiation 16) regional flux verification from buoy arrays
1d	Surface CO2 flux	2	nil	17) pCO2 from VOS 18) fluorescence from VOS
1e	Sea Ice	2	passive and active microwave from satellites	19) ice drifters 20) *in situ* ice thickness
2a	Upper Ocean monitoring	2	regional upper ocean monitoring	21) T(z) VOS XBTs 22) T(z) S Hemisphere supply vessels 23) Autonomous floats
3a	Global inventories	3	nil	24) time series of T, S & carbon 25) repeat sections for water mass formation
2c	Global seasonal to interannual prediction	4	nil	nil
3b	Global circulation and transport	4	long term operational sections, river discharge monitoring	nil

Elements to be added in support of a sub-goal often contribute to other sub-goals, and elements required for a specific lower priority sub-goal are not repeated if they are required for a higher priority sub-goal.

The emphasis placed on surface wind-stress and SST derives from their role as forcing functions (or surrogates) for a wide range of climate and non-climate problems. The emphasis placed on ENSO prediction is a consequence of the economic benefits to be realised from the resulting services, and reflects the scientific advances made by the TOGA that enable them. Sea level change was reasoned to be one of the few long term climate records that can be readily maintained and has a high profile in the area of climate change. Both SST and sea level change are valuable indicators which can be tracked through thousands of years of climate change because of their links to sediment characteristics, fossil foraminiferal deposits, and coral growth.

The Panel also made recommendations concerning actions necessary to make effective use of such data in providing advice. To illustrate their thinking they envisaged three types of activity:

a. the preparation of a climate assessment, characterised by the application of improving knowledge and quality controlled past data to obtain the best possible interpretation of those data holdings;

b. the use of data to improve and validate interpretative models, characterised by the joint use of models and data to constrain and test the former for bias and variability and to allow the best possible use of available information through data assimilation processes.

c. to support numerical prediction, in particular of seasonal to inter-annual variations, typically through the use of coupled ocean-atmosphere models.

The most difficult problems to be solved in providing credible advice about climate, to policy makers and industry, are scientific. Therefore it is reasonable to accept the views of this broadly-based joint Panel, drawing upon the work of the IPCC for example, as the most representative available of customer need. However, the OOSDP emphasised the need to keep their recommendations under review. They went on to recommend the formation of a successor international panel to co-ordinate the activities of the national institutions that would create and act upon an implementation plan. Such a panel, known as the Ocean Observations Panel for Climate (OOPC) was set up by the JSC of the WCRP and met for the first time in March 1996. It is cosponsored by that JSC, J-GOOS (now absorbed into the GSC) and the JSTC of GCOS.

The OOPC accepted that events had moved on since publication of the OOSDP Report – in particular with the success of the TOPEX/Poseidon mission – and that it must devise a strategy for better defining user needs for the products enabled by OOPC activities and the benefits to be obtained.

The work plan of the Panel is:

- to prepare end-to-end illustrative examples based upon the use of:
  - **a.** XBT and TAO observations in ENSO monitoring and prediction;
  - **b.** precision altimeters and tide gauges in monitoring long term sea level change;
  - **c.** marine data in better understanding air-sea coupling.

  This work is ongoing.
- to provide scientific advice to active implementation panels and agencies, in particular for SST, on the distribution of hull mounted sensors and drifters and the use of ATSR and geostationary satellite sensors.
- to encourage the use of OSEs and OSSEs to refine the design of the Ocean Observing System for Climate.

At its meeting held during 11-13 February 1997 the Panel recommended the creation of a Global Ocean Data Assimilation Experiment. This is described in section 6.7.

More recently, the OOPC has defined accuracy and sampling goals for the measurement of the physical variables required for a number of climate applications.

4.6.3 Health of the Ocean

The need

The Health of the Ocean (HOTO) module of the GOOS is intended to provide the basis for determining prevailing conditions and trends in the marine environment in relation to the effects of anthropogenic activities, particularly those resulting in the release of contaminants to that environment. A strategic plan designed to achieve this goal was formulated by the Panel and published, (IOC, 1996a). A summary of the findings and conclusions has also been published by Andersen (1997).

The primary users represented by the HOTO Panel are national and state/local governments wishing to maximise socio-economic benefits derived from use and sustainable development of ocean and coastal areas. The HOTO plan embodies guidance on marine pollution monitoring devised within the GIPME Programme, the London Convention 1972, the Global Programme of Action for the Prevention of Marine Pollution from Land-Based Activities, the Regional Seas Programmes of UNEP and a range of regional Marine Protection Agreements.

Planning within the context of the GOOS

The Panel's particular contribution has been to identify and prioritise the biological, chemical and physical environmental variables that should be monitored in order to achieve the above goal. They determined that the following classes of contaminants and/or analytes merited attention:

artificial radionuclides
aquatic toxins
pathogens
pharmaceuticals
synthetic organic compounds
oxygen
petroleum hydrocarbons
polycyclic aromatic hydrocarbons
trace metals
suspended particulates
phytoplankton pigments
nutrients

4.6
DESIGN OF THE GOOS

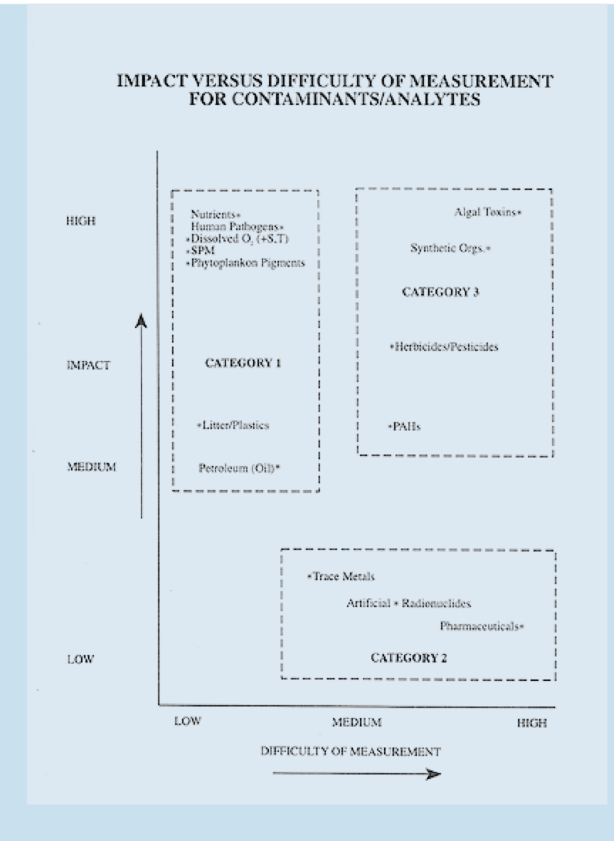
Balancing user needs and scientific/technical feasibility

These groupings of contaminants/analytes were subsequently characterised in terms of ease of measurement, significance as indicators of the health of the marine environment and relationships to socio-economic activities in the coastal zone. For example, it is relatively easy to monitor suspended particulate matter (SPM) but sediment transport can give rise to considerable habitat disruption and direct and indirect adverse effects on marine organisms and amenities in the coastal zone. Category 2 analytes may be important locally, but are generally of low significance in the marine environment as a whole.

The Panel recognised that contaminant loads alone do not provide comprehensive quality indicators in the marine environment. Accordingly, they called for the capture of information on levels and trends in contamination in combination with measures of associated biological effects. Indices of biological stress at the level of the sub-organism, individual, population and community are required. The Panel characterised such biological measurements in terms of their ease and specificity of measurement and their ability to predict significant compromise to populations of marine organisms including biodiversity.

The Panel also placed emphasis on the development of assimilative capacities of coastal zones for contaminants and the reclamation of existing data on contamination and community response. Priority measurements were identified on the basis of the combination of feasibility and value to the objectives of the module.

Needs articulated in this way will be met by a series of discrete, localised and well-targeted monitoring programmes, using uniform techniques, common standards and data management processes to achieve both regional and global coherence and coverage. Each such programme is to be designed in detail, particularly in terms of temporal and spatial measurement frequency, to meet clearly-defined goals.



That design process has begun in the form of regional blueprints that have been generated by members of the HOTO panel (IOC,1998b). Such blueprints review the particular physical and biological setting of a region, the appropriate socio-economic and management issues, current institutional arrangements, the Conventions in force and regional capacity. On this basis regional management goals, priority measurements, a sampling strategy and typical data products and related issues are identified.

The relevance of several existing programmes (3.6) with components corresponding to HOTO measurements has been noted. These include GIPME and its Marine Pollution Monitoring Programme (MARPOLMON), that are assisting GESAMP to deliver periodic reviews of "The State of the Marine Environment", the International Mussel Watch Programme and several regional monitoring and assessment programmes. The Panel believes that further development of the Mussel Watch Programme, to include data on the status of sentinel organisms, would accelerate the acquisition of data on the health of the biota. GIPME is providing a wider range of inputs of relevance to HOTO needs, including the development of sampling and analytical techniques, preparation of reference materials and the conduct of intercomparison exercises and training workshops. The Regional Seas Programmes of UNEP and the UNESCO Coastal Marine Ecosystem Co-operation Programme (COMAR) were also cited. The core research projects of the IGBP such as LOICZ (see 3.4.3) are also of considerable relevance.

Monitoring is necessary but insufficient to achieve the goal of this module. The prediction of the transport and fate of contaminants is essential. Prediction is made particularly difficult because contaminants can reside in aqueous, suspended particulate, sedimentary particulate and biological phases (GESAMP, 1991). Both this fact and the potential for exchanges across these phases must be considered in the design of particular systems.

Implementation of the HOTO module design will require support for physical measurements (salinity, temperature, etc.) in common with the Living Marine Resources module. This stresses the need for multidisciplinary implementation of the GOOS whether at local, regional or global levels.

4.6.4 Living Marine Resources

The need

The goal of LMR GOOS is to provide to those concerned with the harvest and conservation of living marine resources, operationally useful information on changes in the state of living marine resources and the ecosystems within which they exist.

The objectives are:

- to obtain from various sources, relevant oceanographic and climatic information along with fishery and other information on the marine ecosystems,
- to compile and analyse these data,
- to describe the varying state of the ecosystems, and
- to predict the future states of the ecosystems on useful time scales.

An ad-hoc planning workshop for this module was held in March 1996. The objective was to identify user requirements for oceanographic data on living marine resources, and to give advice on the design and implementation of a system of observation, data assimilation and modelling to monitor and predict the state of the marine ecosystem at regional and global scales; especially emphasising those features of the living marine resources that are of economic, social and environmental importance.

The workshop created a list of classes of users and beneficiaries for identified types of product and attempted to prioritise implementation accordingly. Users include:

- international, national, regional and local regulatory agencies responsible for managing the state of the marine environment, wildlife, fisheries, shell fisheries and aquaculture;
- the fishing industries;
- public health organisations;
- non-governmental environmental and wildlife organisations;
- managers of marine parks and wildlife reserves;
- agencies concerned with climate change and its impact on the environment.

The primary need of the first two of these categories is information on the present states of target stocks and predictions of their future states. Interest is primarily in harvested fish and shellfish and in creatures affected by the fisheries, including little-harvested species such as marine mammals, turtles and seabirds.

It was noted that information and products supplied will have enormous value to regulatory authorities preserving fisheries, but it would be difficult or impossible to persuade the fishing industry to pay for the system creating them. The Panel also noted that benefits will tend to fluctuate regionally and temporally as processes or events vary. No attempt was made to evaluate the foreseen benefits.

Balancing user needs and scientific/technical feasibility

The needs of these users were characterised, in the form of actual and predicted maps of the distribution of a range of trophic levels in the marine ecosystem, extending from phytoplankton to top predators. It was agreed that, although such information was needed, the problem of predicting recruitment and mortality at the larval and juvenile stages of fish growth remains in the research domain at present.

Scientific projects such as GLOBEC are to be counted among the potential users of LMR products but will also contribute to the scientific basis for the development of the LMR programme of work.

Planning within the context of the GOOS
In addition to the ecosystem data referred to above, it was noted that predictive models require concurrent radiation and physical oceanographic and meteorological data. The range of methods available to capture such data were reviewed – see also (GLOBEC, 1993a). The particular problems of modelling the highly non-linear, linked physical, biological and chemical processes involved and the difficulty of identifying and measuring key variables, were emphasised.

Priority tasks were identified as:

- identification of information being collected by existing agencies, development of strategies to correct deficiencies, concentrating on the large scale distribution of lower trophic levels and fish stocks;
- in conjunction with GLOBEC, development of sampling and modelling methodologies, based on the nested hierarchical approach;
- the development of operationally deployable instruments to characterise phytoplankton and zooplankton assemblages, and of techniques for rapid, reliable analysis of the resulting data;
- establishment of mechanisms to achieve involvement of agencies in the programme, in particular FAO;
- creation of an LMR Panel to refine and extend the advice of the ad hoc workshop, and develop a plan for the design and implementation of the required observing system.

To the extent that contaminants in the marine environment are a determinant of its carrying capacity there is close coupling between this and the HOTO module. Many fish stocks breed in regimes of the Coastal module such as estuaries, lagoons and mangrove forests. It is also well known that primary production of LMR is dependent on large scale dynamical changes in the ocean, in particular when upwelling brings nutrients to the euphotic zone where they can be used by the phytoplankton. So there are strong connections with the other modules of the GOOS.

In summary, for the purposes of designing the GOOS, the essential task set by this module is one of monitoring and modelling critical parts of the food webs from bacteria and phytoplankton, through herbivores, carnivores and top predators, as a function of the environment in which the biological and chemical processes are taking place. Numerical (deterministic) modelling of such processes is the province of GLOBEC (e.g. GLOBEC [1993b] and Robinson and Dickey [1995]) and is recognised to be at the frontiers of what is possible today.

4.6.5 The Coastal Environment

The need
The coastal zone includes river drainage basins, the coastal sea, wetlands, estuarine, and marine habitats. Inputs of materials, sediments, energy, and waste from land, sea, and air tend to converge in the coastal zone. In all maritime states the human population is concentrating in the coastal zone. Climate change, sea level change, and inputs of nutrients and contaminants, combined with translocation of nonindigenous species and habitat destruction are among the most ubiquitous threats to the coastal zone.

Most of the economic uses and social benefits of using the sea and enjoying its amenities arise in the coastal zone. All the major industries, offshore oil and gas, fishing, aquaculture, shipping, ports, and recreation have their greatest concentrations of activity on the continental shelf and the coast. These commercial activities need GOOS services to ensure that they can be developed and operated in a sustainable way, while protecting the coastal environment. Regulators and safety agencies need GOOS services to guide them in managing the coastal ecosystem, and protecting human life and property from danger. Ecosystem services provided by the coastal aquatic environment have been ranked in order of estimated value by Costanza et al. (1997).

Recent coastal flood and hurricane damage in several countries, with the loss of thousands of lives, underlines the threat. The predicted rise of sea level of the order of 30-50 cm in the next 100 years will greatly increase the risk. Climate change will have effects on coastal ecosystems which are still unpredictable, but need to be understood. The achievement of such predictive understanding of coastal ecosystems depends upon development of regional to global networks that link observations and analysis.

Planning within the context of GOOS
At meetings of I-GOOS and the IOC Assembly, delegates repeatedly stress that for most countries the major benefits will be generated in the coastal zone, and the developing countries in particular want to see rapid development of the coastal products from GOOS.

The need for a GOOS Coastal Module (C-GOOS) was assessed, and the terms of reference for a Coastal Panel, were formulated in February 1997 (IOC,1997d). The Panel was set up and held its first meeting in April 1998. The Panel is charged with producing strategic implementation plans for an end-to-end system which will provide data products needed by coastal states. The Panel has identified the following goals:

- determine user needs in the coastal zone and specify the environmental data and products required;
- identify regions where present monitoring efforts are inadequate and formulate plans to fill these gaps;
- identify inadequacies in the measurement programs of present observation systems in terms of variables measured, scales of measurement, and usefulness;

- promote regional to global co-ordination and integration of monitoring, research and modelling;
- promote the design and implementation of internationally co-ordinated strategies for data acquisition, integration, synthesis and dissemination of products;
- promote the use of regional to global networks of observation systems to improve now-casting, forecasting and prediction of the environmental change in the coastal zone; and
- promote capacity building in developing nations to provide the opportunity to contribute and participate in C-GOOS as a key feature of the GOOS Strategic Plan.

The Coastal Panel has agreed the following user-driven operational categories:

- preserve healthy coastal environments,
- promote sustainable use of coastal resources
- mitigate coastal hazards, and
- ensure safe and efficient marine operations.

These categories are used to define the globally ubiquitous issues of the coastal zone:-

Table 1. Globally ubiquitous issues organised according to operational categories for coastal products and services.

OPERATIONAL CATEGORY	ISSUE
Preserve Healthy Coastal Environments	habitat loss and modification (e.g., wetlands, SAV, coral reefs)
	nutrient overenrichment (e.g., eutrophication, hypoxia/anoxia)
	toxic contamination, oil spills
	diseases in marine organisms
	harmful algal blooms
	nonindigenous species
	biodiversity
Promote Sustainable Use of Coastal Resources	exploitation of living resources
	mariculture (pond and open water)
	saltwater intrusion
Mitigate Coastal Hazards	flooding, storm surges, tsunamis
	wind: tropical storms
	erosion
	sea level rise
Safe and Efficient Marine Operations	safe navigation
	efficient maritime commerce,
	ports, construction
	exploitation of nonliving
	resources, oil, gas, minerals
	spills of hazardous materials (oil, chemicals, radioisotopes)
	ballast water (e.g., transport and release of nonindigenous species)

Discussion

The coastal zone exhibits a wide range of physical and biological marine processes, and therefore many concerns of C-GOOS have to be co-ordinated with the analysis of OOPC, HOTO and LMR panels. There must also be co-ordination with national and regional GOOS projects, and with relevant science experiments such as LOICZ, GCRMN, Mussel Watch, HAB, MARPOLMON, DIVERSITAS, Coastal LTER networks, and GCOS and GTOS. Priorities will have to be established so that limited resources can be effective. There has to be a definition of functional groups of coastal systems so that experience from one area can be compared with others, and lessons learnt can be applied elsewhere. LOICZ is using a statistical cluster analysis to develop a coastal classification scheme. This may be modified by use by GOOS. A coastal classification scheme should consider the following:

- patterns of external forcing, meteorology, terrestrial inputs, exchange with ocean;
- habitat characteristics, circulation regime, size, shape, depth, benthic substrate, nature of the margins; and

Balancing user needs and scientific/technical feasibility

- scaling relationships for comparative analysis: e.g., drainage basin area relative to area and volume of the receiving body of sea water; anthropogenic nutrient load as a proportion of total load; surface area to volume; freshwater fill time; tidal relative to non-tidal flows; benthic production relative to pelagic production.

Conclusions for GOOS
Pilot Projects are needed that will demonstrate that coastal data and information can be used on larger scales that are locally relevant. These must have a reasonable chance of success.

The Coastal Module is a spatially defined concept rather than a topic or user defined concept, and it therefore overlaps with all the other GOOS Modules in the Coastal Zone. This has been clear since the early days of GOOS, and the documents published by all the Module Panels, including C-GOOS, stress the need for collaboration without duplication. This principle now needs to be put into action for the implementation of GOOS.

The priorities of research tend to create a bottom-up design perspective, while the needs of the user communities and national delegates to GOOS require a top-down managerial approach. Critical links between these "end-members" will enable the precise definition of features of environmental change which have to be assessed and forecast in real time (e.g. water depth, wave field, harmful algal blooms) and those which can be modelled or predicted with considerable time lag on monthly to annual timescales.

Potential customers for GOOS data and products have been identified by various national and regional groups (e.g. the GOOS Capacity Building Panel, the C-GOOS Workshop (IOC, 1997d), the US Coastal GOOS Workshop, and reports by NEAR-GOOS and EuroGOOS.) More surveys need to be made, especially in developing countries to assess their detailed requirements.
There is a need for continuous assessment and feedback from customer groups, so that the design and up-grading of services can be planned.

4.6.6 Marine Meteorological and Oceanographic Services

The need
This module Panel has reviewed existing and foreseen requirements for operational marine meteorological and oceanographic services, and current capabilities in key areas. The resulting information has been used to assess the implications for a GOOS with the scope, principles and capabilities described above, and to identify where priorities for action lie.

Not surprisingly, the majority of the required services relating to the closely coupled boundary layer of the atmosphere and surface layers of the ocean are provided currently by meteorological services in the public and private sectors. However, there are several areas where the GOOS would add value, in the form of more comprehensive or higher quality services. The deficiencies may be characterised as follows:

- the lack of international infrastructure in the capture, exchange and processing of non-meteorological data, to mirror the WWW of operational meteorology, that is capable of supporting real-time services and operates with genuine international standards and quality assurance (at present problems are solved on an ad hoc, bilateral basis, and without integration of disparate data – currents, wind, wave, algal bloom and oil pollution data for example);
- a tendency to piecemeal investment in end-to-end systems, exacerbated by commercial suppliers of equipment with sectoral interests;
- a general lack of data relating to the maritime environment, particularly towards the poles, in the tropics and within the EEZs of developing countries;
- the absence of 'open-ocean' forcing conditions, required to extend the predictability of storm surge forecasts for example;
- the absence of reliable bathymetry, required for oceanographic modelling;
- a general lack of resolution in oceanographic models and hence in the precision and accuracy they offer.

Planning within the context of the GOOS
To better meet the needs of end users of specific marine meteorological and oceanographic services, the priorities (Komen and Smith, 1997) are judged to be:

- for ocean wave forecasting – instrumental observations of wind speed and direction, of increased accuracy either *in situ* or from satellites, and their distribution in real-time, and improvement in the quality of medium range forecast winds;
- for the prediction of tsunamis, produced by submarine disturbances – the most useful GOOS contribution is likely to be real time collection of open ocean sea level measurements and improved bathymetry;
- for storm surge forecasts and warnings – the operational services in the North Sea, provided by the UK and the Netherlands, are good role models. Knowledge of the meteorological forcing, bathymetry and coastal geometry are critical, and 3D models generally provide better results than those of 2D. In the tropics the need for and difficulty of prediction of the meteorological forcing e.g. by cyclones, is the major unsolved problem.
- for sea ice services – the primary requirement is:

a. for more accurate discrimination of ice cover at the ice edge where a mixture of open leads and solid ice prevails (Cattle and Allison, 1997), and

b. for more comprehensive prediction of small icebergs in open water where they are a hazard to navigation that can only be mitigated at present by avoidance of the area, sometimes with attend penalties for transit times and distance run.

4.7 Conclusions

The value-adding process has been outlined and the functionality of the component parts described, in the context of a data and information management system that is consistent with the underlying strategy of the GOOS and the other members of the G3OS. The important features of that strategy for the design are the commitment to a distributed system and incremental implementation, building upon foundations that have been catalogued in Chapter 3. Such an approach enables a pragmatic design, i.e. one which makes use of serendipity and experimentation. ***The emphasis is then upon a clear understanding of what products and services are required and on good intelligence about what information and processing capability are available and how to access them.*** The module Panels are presently responsible for the former and a proposal to assist with the latter is included in chapter 5.

There are some fundamentals relating to useful accuracy and temporal and spatial scales, that are set by considerations of signal and noise and the environment respectively.

Although the state of planning is at a different level within the individual Modules, all have identified users for information, products and services that might be supplied as a result of GOOS. In some cases, the individual products have been characterised.

To a greater or lesser degree of detail ***all of the Panels/Workshops have identified the marine variables that should be subject to long-term, systematic monitoring in order to meet those particular needs.*** The OOSDP has gone on to discuss the space/time scales of variability that dictate the design of an observing system that will meet identified needs, and to suggest those system elements that exist and where enhancements are required. The OOPC is providing scientific advice to existing deep ocean monitoring programmes to maximise their effectiveness for climate purposes, and seeking to influence relevant space programmes.

The OOSDP has described and Coastal Workshop has outlined the measurement technology available to meet their needs.

The OOSDP and HOTO Panel have indicated where priority should be given to enhancing capabilities. The Marine Services Panel has focused upon deficiencies in the available end-to-end system, and suggested where enhancement would help to meet needs in their area of concern.

All the Panels recognise that a data processing system, based, in particular, on the use of predictive models, is necessary to create the products and services that justify the investment in observing systems. All have identified the R&D programmes that are likely to deliver such models and the OOPC has proposed a major experiment (GODAE) to encourage development and assessment of such models, assimilating data in real-time.

It is evident that the user needs of the HOTO, Coastal, LMR and the Marine Services modules are focused on the coastal and shelf domains and those of the Climate module are primarily concerned with the open oceans. That is not to deny the sensitivity of the former to open ocean processes nor the significance of the coastal regime for climate. However the realisation does provide a basis for segmentation of implementation, as discussed further in chapter 6.

It is conceived that local operational services that generate products needed by end-users will be based on high-resolution, local-area models tailored to those products and fed by observations collected within or close to the operational area, mainly but not exclusively in coastal seas. Once those local models and observations are optimised, the limits to predictability in the products supplied to end-users will be determined in part by what information is available about future changes in the open ocean boundary conditions. That information will be provided from global models fed by global observations.

Therefore although the information may be partial and qualitative in some cases, of the questions raised in paragraph 4.5.1, answers are available to nos. 1-4 and general guidance is available for no.7. The remainder are readdressed in chapter 5.

5

A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Material is now available to guide the implementation of the GOOS. It includes:

- *the conclusions of chapter 3 that emphasise the strength of the intellectual, legal, material and organisational foundations that are available.*
- *the essential design considerations of chapter 4.*
- *the agreed Implementation Strategy, summarised in chapter 2.*

Despite this guidance, it is not feasible at this time to draw up a detailed implementation plan for the whole of GOOS. Not all of the planning modules have reported yet. Furthermore, in practice and in keeping with principles P8 and P9 of section 1.4, individual nations and agencies, either singly or jointly, will decide what is affordable in relation to their specific priorities and act accordingly.

Introduction

Nevertheless, in keeping with the principles D1 and P1, P5 and P6, it is appropriate to set out a framework for implementation within which individual, more detailed sub-system plans can be formulated, in the knowledge that they are likely to be coherent and compatible with other initiatives, will be consistent with best practice and will contribute effectively to the wider purposes of the GOOS. That is the objective of this chapter.

***Section 5.2** summarises and amplifies the phases of implementation drawn from the GOOS Strategic Plan and introduced in section 2.4.*

***Section 5.3** sets out a process for establishing priorities for implementation, focusing on phase 1, planning and technical definition.*

***Section 5.4** demonstrates the implementation required for phase 2 (pilot projects and operational demonstrations)*

***Section 5.5** demonstrates the implementation required for phase 3 (existing systems) and develops the concept of an Initial Observing System*

***Section 5.6** suggests a thematic implementation to reflect the distinct coastal and open ocean domains of the GOOS, to maintain coherence in planning, to give effect to capacity building and as the basis for implementation of phases 4 and 5.*

***Section 5.7** proposes priorities for further action in phases 4 and 5, based on the recommended thematic structure.*

The GOOS implementation phases

5.2 The GOOS Implementation Phases

IOC (1998a), summarised in chapter 2, makes it clear that the GOOS will be dependent upon commitments made by participating nations through their agencies, by providing new facilities in the form of observing platforms, consumables, data and modelling centres and distribution networks for example.

As noted in section 2.4, the GOOS is to be implemented in five overlapping phases. At this stage, attention is focused on the first three of these. In the future more attention will have to be devoted to phases 4 and 5. It is emphasised that the phases do overlap; all implementation has to be preceded by considered design and planning but such preparatory work cannot be carried out simultaneously for all components.

Phase 1:
Planning, Design And Technical Definition:

As expected, planning has not been uniform, partly due to the difficulty in determining what end-products are required and can be justified and, hence, what additional data capture and value-adding systems should be put in place, particularly for the observable non-physical variables. Secondly, only certain variables can at present be measured reliably because of the lmitations of existing technology. Significant progress has been made on the Climate and Health of the Ocean modules, and the Ocean Services module has identified a number of deficiencies in current systems. The priority task in this phase is to refine user needs and from them the systems to be put in place over the long-term. Inputs can then be progressively combined to achieve coherent and comprehensive implementation plans. It is impractical to assume that this will be achieved in all cases without experimentation - hence the need for phases 2 and 3.

Phase 2:
Operational Demonstrations And Pilot Projects:

Such pilot projects and demonstrations are an important developmental stage because they:

- test how a particular GOOS activity will work as a comprehensive and integrated system of data collection and exchange through to modelling and product delivery,
- provide an impetus to technologies such as instrumentation, sensors, or communication, model development or data assimilation, and reveal the areas for scientific research needed to support GOOS, and
- are often an essential step in convincing agencies that a particular proposal is an achievable mission and a worthwhile investment.

Some pilot projects will be designed as ‘proto-GOOS’ systems from their inception, others may focus initially on one particular aspect of the eventual GOOS. Later, such projects might expand to develop the end-to-end data-to-product system and deliver to a broader range of users. The regional initiatives of EuroGOOS and NEAR-GOOS are current examples of such ‘proto-GOOS’ systems.

Phase 3:
Immediate Implementation Using Existing Systems:

Many activities capable of becoming part of the GOOS are already fully or near-operational (in the sense of having a funding for continued operations and a back-up plan) through national observing systems, international organisations and bodies or through large-scale scientific programs, as described in chapter 3. The most common deficiency is lack of adequate geographical coverage. Because they exist, these components have little risk associated with them but do need to be used effectively to implement the GOOS to deliver tangible benefits. A GOOS Initial Observing System can be devised now from some of the existing international organisations and bodies (see “An Initial Observing System for the GOOS”, below).

Phase 4:
Gradual Operational Implementation of the ‘Permanent’ or Ongoing Global Ocean Observing System:

Aside from the elements of existing systems now incorporated into the GOOS Initial Observing System (Phase 3), continued integration into GOOS of other international components, as well as national and regional activities is envisaged, along with the creation of new systems (e.g. such as operational remote sensing from satellites), and with expansion of present observing networks to fill geographical gaps that limit effective ocean and climate forecasts.

Phase 5:
Continued Assessment and Improvement in Individual Aspects and in the Entire System:

It is essential that the performance of the system and of its individual components are reviewed regularly to ensure that each is working efficiently and effectively to meet the needs of what is likely to be a growing community of users with different needs, and that the level of redundancy in the system is appropriate.

Implementation of the various phases beyond the first requires the following activities within a systematic process:

i. Combine and enhance observations already being made routinely, such as sea level, sea surface temperature, wave climatology, upper ocean temperature, surface meteorology and nutrients, and cooperatively address their incorporation within a common plan, in the process recognising the growing needs also of resource managers, e.g. for biological information;

ii. Identify existing ocean observing activities relevant to GOOS that are or will be of limited duration and/or geographical extent (satellite missions, surveys, experiments) and develop and promote strategies and sponsorship to encourage their continuation.

iii. Establish or accredit data centres to receive the data and apply appropriate GOOS standards and the management of implementation according to GOOS plans;

The GOOS implementation phases

- **iv.** Secure appropriate GOOS-identified infrastructure for data distribution and delivery;
- **v.** In parallel, devote effort to the generation of computational and interpretation tools, the implementation of appropriate training, the provision of basic infrastructure (PCs, application software, web access, models) to broaden the hands-on usage of GOOS data. All these contribute to the building of a scientifically competent user community;
- **vi.** Encourage the production of GOOS ‘demonstration’ end-products (models and case studies) that have relevance to identified target user communities (eg, shipping, oil production, fishing, coastal protection);
- **vii.** Build demand; introduce a program of active promotion of the GOOS, using these products and successes in implementation as a focus.

Realistically, the other essentials of an effective operational system, such as timely data communication and robust QA procedures, are likely to be imported from operational programmes, although climate research programmes demand many of these disciplines and have growing experience in the field.

The sponsors and the space agencies in the form of the CEOS have made it clear that they expect the implementation strategy for the GOOS to be compliant with the emerging IGOS, one of whose purposes is to ensure coherence and compatibility of investment. National and international funding sources take a similar line. This is a significant task because, as shown in chapter 4, there are many interdependencies among individual components or elements of practical environmental information systems. The problem is exacerbated by the inevitable piecemeal implementation advocated above.

The solution lies in the creation of as much coherence as possible in the inevitable segmentation of investment and an effective coordination mechanism. There are several ways of achieving this. First, through implementation of complete end-to-end systems on a regional basis. Second, by gathering together particular types of reasonably self-contained service or activity, that might be characterised as themes. Third, through phasing of the implementation, so that whilst the long term goal is clear and committed to in-principle, investment in the later stages is contingent upon the achievement of particular sub-goals in the early phases. Coherence can be enhanced if the milestones between individual programmes are compatible. In practice, all of these techniques for achieving a coherent but segmented implementation can be deployed in concert to a greater or lesser extent, depending upon the particular circumstances.

The establishment of priorities is a further, singularly difficult task in international, cooperative ventures. There is a tendency to produce action lists that are comprehensive, but undifferentiated. The key to success seems to be to identify priorities through processes that are either as objective as possible and based upon hard evidence or, at the very least, have widespread support.

The remainder of this chapter suggests how these two tasks of identifying high priority actions and managing a coherent but segmented implementation are to be accomplished.

5.3
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Guidelines for establishing priorities in phase 1

This section covers the strategy for prioritising actions, particularly during design and technical definition but which are then carried forward to later phases. The objective is to identify those actions that will deliver most for a given investment, that are most practical with existing technology at minimum risk. These will be referred to as of 'high priority'.

The use of cost benefit analysis to compare alternative options for investment based on economic considerations is discussed in section 3.3.3. Brown (1995) has shown that there are substantial unsolved technical difficulties for the method when applied to major S&T programmes such as the GOOS. Nevertheless it is argued, on the basis of experience gained during TOGA, that in its current state of development the technique can be applied when there is at least some practical experience available from which empirical evidence as to outcome, investment and risk can be gleaned. It is one of a class of techniques that involve the use of past experience and analogues from which an extrapolation can be made. Other examples include scaling-up from a pilot project and the transfer of experience from one region of the globe to another.

Another approach is to assess the outcome of an investment according to the impact it is likely to have on the problem in hand and the feasibility of implementing the investment successfully. Actions that score heavily on both counts are assigned higher priority than those which do so on one or the other. This effectively ignores the size of the investment but seeks to maximise output and minimise risk.

Where there is insufficient practical experience available to know how best to proceed but a conviction that the goal will justify the use of discretionary R&D resources, a demonstration project may be indicated. For this to be given high priority the project must have widespread community support gained through some form of peer review or equivalent process.

Where governments have made formal commitments of the kind contained within the FCCC and other Conventions, it is assumed that they will wish implementation to have high priority, provided that mechanisms to make specific choices are based on the above methodologies.

All of these approaches are applied in order to identify the high priority actions, but are first amplified and illustrated further here.

5.3.1 Scaling from past experience and by analogy

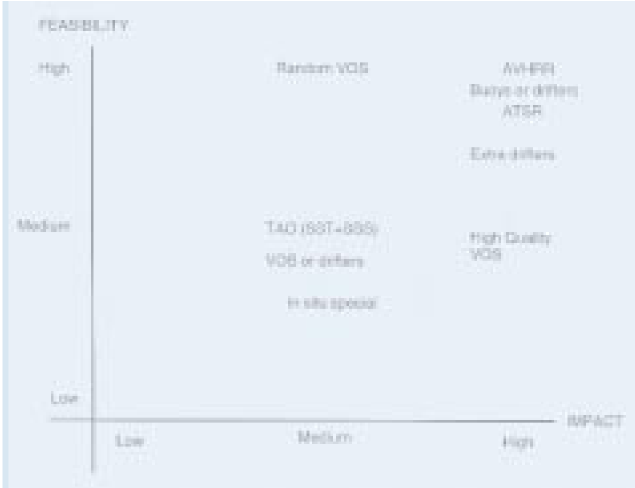
In economic terms this approach is advantageous because the R&D and perhaps some other fixed overhead costs are substantially sunk. Even if the fixed costs are not sunk, more output may be obtained pro-rata by increasing the number of units from which data are obtained.

Provided that there is a sound rationale for the output, obvious examples of this are:

- investment in moored and drifting buoys, of various kinds, whose value has been demonstrated in operational programmes such as the WWW or R&D programmes such as MAST, WOCE and TOGA;
- the continuation of a long-lived record;
- the addition of sensors that meet the joint criteria of high impact and feasibility to existing platforms (of opportunity);
- the expansion of the role of NWP centres to carry out ocean modelling, particularly where this can be accomplished within available resources and without significant impact on the existing mission.
- replication of proven monitoring and associated operational services from one part of the world to another, or to fill gaps in coverage.

5.3.2 Through joint assessment of impact and feasibility

This is a technique used to good effect by the OOSDP and HOTO Panel. Section 4.6.3 includes examples produced by the HOTO Panel and the following is adapted from OOSDP (1995). It illustrates the views of that Panel in 1995, about the joint impact and feasibility of various components of the observing system recommended to provide SST field variability on monthly and longer timescales, where feasible in combination with SSS.



The diagram emphasises the high impact and feasibility for these purposes of the AVHRR instrument and moored and drifting buoys, whilst reflecting the lower quality and, hence, impact of current VOS measurements and the difficulty of implementing a higher quality VOS system. Since 1995, both the ATSR and TAO array have been added to the operational system, as recommended.

5.3.3 Through demonstration or development projects having community support

Examples here are demonstration projects such as those of EuroGOOS, that are subject to the MAST or 'Framework' peer review process, or where the space agencies have committed to fly, operate and make data available from demonstration instruments capable of monitoring properties of the marine environment. The GODAE, with its widespread endorsement, selection and acceptance by the CEOS, is a particular example of this.

Development projects that have been endorsed by a similar process are also given high priority.

5.3.4 To give effect to inter-governmental Conventions and Agreements

The commitments made by signatories to various Conventions are described in section 3.1.
Governments need data on which to base their national reports under these Conventions. The Conferences of the Parties, the secretariats, and the subsidiary scientific and technical bodies need information on the state of the environment, resources and processes to which the Conventions and actions plans are directed. Only reliable observations over time can demonstrate if the measures taken under the Conventions are effective. The GOOS should give priority to the reliable provision of the required information concerning the marine environment.

5.4
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Current implementation (phase 2)

Phase 2 is being implemented through the development of pilot projects and operational demonstrations.

System, project or programme	Location	Primary Theme[6]	Temporal contribution	Current Focus
NEAR-GOOS	Sea of Japan Yellow Sea & South China Sea	coastal/shelf	current & ongoing	data management
EuroGOOS	Mediterranean, Baltic & European NW shelf	coastal/shelf & capacity building	current in the Baltic, building to operations elsewhere during 2000-0	operationaloceanography services and capabilities to provide
EuroGOOS	Arctic & Atlantic Oceans	open ocean	building to operations during 2000-06	climate research & Boundary condition provision
NOAA GOOS Center (AOML)	global	open ocean	current and ongoing	efficient deployment of NOAA marine investments; new observing networks
Pilot Research Moored Array in the Tropical Atlantic	Equatorial Atlantic	open ocean	current to 2000	seasonal to interannual prediction
Global Ocean Data Assimilation Experiment (GODAE)	global	open ocean	building to the experiment in 2003-05	demonstration of real-time data assimilation and modelling

The NEAR-GOOS (6.3) has been designed and is being implemented in the context of the IOC WESTPAC Regional structure, as a result of agreement established at intergovernmental level. The participants:

– have chosen to establish an effective data management system as their first priority.

– are heavily committed to the exchange of technology and expertise; data management provides many opportunities for this;

– are considering the development of numerical models to underpin forecasts.

The ingredients that seem to be making a success of the EuroGOOS endeavour (6.4) include:

– the active participation of the operational agencies that are likely to provide new or improved services, for which there is a demand;

– involvement of the research communities who are able to advise on the feasibility of incremental improvements in capability and their likely impact;

– a comprehensive set of projects that span the local, regional and basin scales;

– a good knowledge of the installed base of relevant observing, modelling and operational information distribution systems;

– significant, prioritised and affordable propositions to place before funding agencies that form part of a coherent, long-term strategy (an example of 5.3.3).

The NOAA GOOS Centre, represents a national commitment to collecting particular kinds of data, which it would do anyway for national purposes, and making them available to the GOOS. It is to be hoped that other nations will follow this lead in the implementation of GOOS.

PIRATA, is an extension of the TAO concept from the Pacific into the Atlantic (3.6.5), to see if an equatorial array of buoys can help to determine the relative strengths of the Pacific (El Niño) and Atlantic signals that control the local climate. It is a good example of the approach described in 5.3.1. If the extension proves useful it may become operational.

GODAE (5.7) will be the first real test of the capabilities of a truly global observing system, integrating and assimilating *in situ* and satellite remote sensing data into global models.

Current implementation (phase 3)

Capitalising on existing observational systems, an Initial Operational System GOOS-IOS has been built from a wide range of contributions that were set up for other purposes but also address, are compatible with and satisfy a sub-set of GOOS requirements. In principle, these programmes can provide contributions to the GOOS as well as to the original groups of clients for whom they were set up. The GOOS-IOS deals primarily with physical systems, to which chemical and biological systems will be added as they are developed.

All of these are good examples of the approach of 5.3.1. The Ship of Opportunity Programme provides valuable data on the character of the upper ocean, through the use of disposable devices launched from a ship on passage (3.6.2). In an analogous manner, the Voluntary Observing Ship network of commercial vessels provides essential data on the surface ocean and meteorological conditions to support weather forecasting world-wide (3.6.3). Both the SOOP and VOS work along trade routes, so fail to cover large stretches of rarely travelled ocean, like the South Pacific, southern Indian Ocean and Southern Ocean. The DBCP coordinates almost all of the drifting buoys deployed across all of the world's ice-free oceans by a multitude of research organisations during WOCE (3.6.7). Gaps tend to occur in the central parts of ocean gyres, where currents are infrequent. The GTSPP (3.6.2) collates information from these and other programmes to produce high quality temperature and salinity profiles of the upper ocean. The TAO array of buoys (3.6.6) underpins predictions of El Niño events. The GLOSS tide gauge stations provide essential information on water levels (3.6.4). The GTS is the WMO's main means of data exchange, supplemented now by the Internet. The GCRMN (3.6.8) is the principal mechanism for monitoring the state of coral reefs world-wide. Ideally all of these systems deserve maintenance on an operational basis, though in their integration into the GOOS consideration needs to be given to the extent of redundancy in the current combination of elements.

System, project or programme	Location	Primary Theme[5]	Temporal contribution	Current Focus	Elements of Observations
Ship Of Opportunity Programme	global	open ocean	current & ongoing	the deployment of probes from ships & data capture	XBT, XCTD
Voluntary Observing Ship Programme	global	open ocean	current & ongoing	meteorological measurements from ships	marine meteorology
Global Sea Level Observing System	global	coastal/shelf & open ocean	current & ongoing	*in-situ* measurement of sea-level	sea surface topography
Global Telecommunication System	global	coastal/shelf, open ocean & capacity building	current & ongoing	operational telecommunication system	communications
Global Coral Reef Monitoring network	global	coastal/shelf	current & ongoing	health of coral reefs & associated ecosystems	scientific and economic assesment
Global Temperature and Salinity Profile Programme	global	open ocean	current & ongoing	oceanographic databases & distribution of related products	real time and n.r.t. SST, XBT, CTD
Data Buoy Cooperation Panel	global	open ocean	current & ongoing	the deployment of buoys & data capture	SST, air pressure
Tropical Atmosphere Ocean Array	Equatorial Pacific	open ocean	current & ongoing	seasonal to interannual prediction	wind, SST, pressure temp-profile, ADCP
NOAA operational satellites	global	open ocean coastal shelf	current & ongoing	weather forecasting ocean remote sensing	met-data SST, sea ice

5.6
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Themes for further implementation

Having taken action on phases 1 to 3, where planning permits we need to consider the steps required under phases 4 and 5 of the GOOS implementation, which it will be difficult to separate at this stage.

In essence the GOOS requires investment in the systems that will sustain operational activities and in methods that ensure that they are used efficiently and effectively. Particularly in an international endeavour where freedom to manage their resources remains with nations, the latter includes the coordination function. The GOOS is also committed to capacity building and this function must be an integral part of the methodology.

Although the initial design of the GOOS is taking place in 5 Modules, further implementation may best reflect the fact that the GOOS contains two coupled but distinct types of monitoring and modelling activity concerned with the domains of:

1. the coastal/shelf regime; and
2. the deep open ocean.

There is a physical basis for this distinction in that unlike the relatively uniform environment of the open ocean, the spatial and temporal heterogeneity of the world's coastal zones is considerable. Much of the exchange between the atmosphere and ocean takes place in the open ocean because of the greater area of contact on a global scale.

In contrast, the vast majority of social and economic activity relating to the oceans and seas takes place in the coastal/shelf domain. In part because of this, there is also a legal basis for the distinction in the jurisdiction, described in 3.1.2, that coastal states have over their territorial waters and EEZ under the terms of UNCLOS, as opposed to the freedom of the high seas.

The planning for the Climate module for the GOOS, that has been preoccupied with atmospheric/oceanic exchange and the large-scale circulation of the oceans, has progressed more rapidly than international planning concerned with the much more diverse, heterogeneous coastal zones. We should note, however, that there are already many local operational services in the coastal zone, which will benefit GOOS.

The proposed distinction is not based upon the modular use of data. The impact of climate change will be experienced as much in coastal zones as in the open ocean and coastal data, gathered on a global scale, will have undoubted value in detecting climate change. There are many naval applications and services for marine transport that require coastal and open ocean information.

Furthermore, there are important couplings between the two domains, exemplified by the manner in which the development of local operational services is likely to proceed, as noted in section 4.7, where the predictability of services in domain 1 is expected to depend upon the provision of boundary conditions from monitoring and modelling in domain 2.

Therefore it is proposed to develop implementation planning within two themes based on physical domains. Underpinning each of these are activities necessary to achieve efficient, coherent and comprehensive involvement of all the parties wishing to participate in the collective endeavour. The themes are defined as follows:

Theme 1 Coastal and shelf monitoring and modelling to contribute to the achievement of objectives 1,2 and 3 of section 1.3, by integrating and meeting the requirements of the Climate, Coastal, Living Marine Resources, Services and Health of the Ocean Modules in this physical domain.

Theme 2 Global open-ocean monitoring and modelling to contribute to the achievement of objectives 1, 2 and 3 of section 1.3 in this physical domain, by meeting the needs of the Climate module, in particular, enabling open ocean services and extending the predictability of regional services, and supporting LMR and HOTO secondarily.

Theme 1 lends itself to local and regional implementation. Inevitably, many of the systems and methods applicable to theme 2 will be implemented first on a basin scale.

To contribute to the achievement of the two themes and of objectives 4 and 5 of section 1.3 the provision of structural support and expertise is required in the form of skilled staff, an effective GPO and associated regional capabilities, to carry out international planning and coordination, encourage adoption of necessary operational procedures and methods, and provide training and other forms of capacity building.

Continuing implementation, assessment and improvement of the ongoing GOOS

5.7.1 Applicability

Throughout unless indicated otherwise, the following guidance is directed at operational, research and aid agencies who have been persuaded that implementation of the GOOS can deliver worthwhile benefits to them and those they serve at a reasonable level of risk. It is hoped that governmental authorities and intergovernmental agencies will be persuaded that, if the guidance is followed, a coherent, effective global system will be created to provide the advisory services they require and wish to encourage and sponsor.

More generally, action is also sought:

by the GPO, and the panels they support, in collaboration with the planning offices of GCOS, GTOS and CEOS:

- to ensure that international liaison, planning and the determination of 'best practice' is on a sound footing and the results are made widely available to governments and agencies in a form that can be readily assimilated. A typical example is in the fields of calibration and validation of remote and *in situ* sensors.

by the sponsoring organizations:

- to facilitate the prioritisation, expression and publication of the needs for marine data, information and advice required by the international scientific organizations, such as the IPCC, other scientific advisory bodies of the Conferences of the Parties of the Conventions and those charged with preparing state-of-the environment assessments.
- to encourage support from the private sector for the provision of such information.

5.7.2 Recommended precursor actions in individual States

For both of the Themes, certain pre-cursor actions may be necessary in individual States where it is suspected that the guidance from the module panels or regional programmes is incomplete or where there may be specific local or regional considerations concerning need, regulatory framework and capability. These actions include:

by agencies, to:

- produce or obtain clear statements of user needs, the management problems that are to be addressed by the particular manifestation of GOOS, and benefits to be realised, e.g. through the conduct of surveys or as a result of research/demonstration projects;
- identify the variables to be measured, the signals and noise to be expected and hence design a suitable sampling strategy;
- specify the value-adding process to deliver the required services, making use of operational capabilities available through programmes such as the WWW and IGOSS;

by government, to:

- consider the need to strengthen the appropriate legal or regulatory frameworks for management action (*vide* the Black Sea and Benguela examples);
- identify and support agencies and other establishments that are capable of carrying out the necessary work.

Where the above have been carried out:

5.7.3 Theme 1 Implementation of coastal and shelf monitoring and modelling

Existing Programmes

The systems/programmes/projects of the GOOS-IOS that contribute to the objectives of the GOOS within Theme 1 are the GLOSS, GTS, NEAR-GOOS, the EuroGOOS projects focused on the NW shelf and inner seas and the GCRMN.

In addition, although not formally part of the GOOS, significant contributions to its objectives in this domain are made by the International Mussel Watch, the pollution monitoring of MARPOLMON/GIPME, the harmful algal boom (HAB) programme, the Continuous Plankton Recorder (CPR) programme and the many national/regional meteorological and oceanographic observing systems and associated services relating, for example, to tidal prediction, storm surge monitoring and prediction, hydrographic, species and water quality surveys and the assessments that they underpin. The existing operational NWP programmes are important sources of surface wind stress and heat flux data. Existing and planned satellite programmes making measurements of SST, wind speed and direction, wave characteristics, biological productivity, ecosystem health and sea-ice cover are relevant. Not all these programmes are currently operational but those that are not, but are relevant to the GOOS, either have plans to become so or are conducting pilot projects with the aim of establishing whether an operational programme can be justified. At this point in time, detailed advice for resource managers (e.g. for sustainable healthy seas, including marine ecosystems and living resources) is being developed by the Coastal, Living Marine Resources and HOTO Module Panels of GOOS. Thus what follows is not yet fully in tune with the needs of that community, whose assistance we seek in developing systems to meet those needs.

GOOS Capacity Building is especially relevant for the large number of developing countries with strong interests in Theme 1.

5.7
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Continuing implementation, assessment and improvement of the ongoing GOOS

A Physical Oceanographic Real - Time System (PORTS)

Modern ports are very competitive commercial operations where information upon which rational decisions to balance safety, health of the environment and commercial viability of the coastal community must be made. PORTS is a decision support system, developed by the U.S. National Ocean Service (NOS), and installed in partnership with a number of ports around the United States. The system integrates real-time observations of currents, water levels and water temperatures at multiple locations with meteorological data to produce nowcasts and forecasts of ocean fields. Information is available to the general public and to provide information for safe and cost-effective navigation, search-and-rescue, hazardous material and oil-spill prevention and response, and scientific research.

Inevitably, regional programmes solve communication, processing, archiving and product generation problems locally – indeed the current phase of NEAR-GOOS is centred on this issue – but an important role of the support function will be to encourage solutions in these fields that have the widest possible applicability.

Timetable
The need for a unified timetable of investment and development is much less within this theme than within Theme 2. To first order, regional initiatives will and should proceed to meet local priorities. Nevertheless, there are some important milestones for those wishing to track and learn from existing programmes. Thus, LOICZ findings and tools are expected to become available during 1998 to 2003 and most of the EuroGOOS regional projects plan to start operations in 2000/1; the Mediterranean Forecast System is expected to begin operational development in 2003 with operations scheduled for 2006.

It is assumed that the implementation of global modelling through GODAE, and precursor initiatives on the basin scale, will provide important information on boundary conditions for models of coastal seas.

The planned availability, until at least 2005, of satellite missions capable of meeting the stated requirements for SST, sea state, ocean topography, sea level, ocean circulation and ocean colour measurements is also relevant.

Recommendations for action
There are already useful lessons to be learned from the distinctive approaches of the EuroGOOS and NEAR-GOOS. The HOTO Panel has provided a clear strategy for achievement of the specific objectives identified by their module.

- ➪ These lessons and guidance should be adopted by future regional manifestations of the GOOS as appropriate to suit the local style of planning and implementation.
- ➪ It will be helpful to increase the potential value of the service to end users, the cause of the GOOS as a truly global venture, and the awareness of the community as a whole if:
- ➪ the EuroGOOS benchmarks of 2000/1 are maintained to bring a number of their demonstration projects to operational fruition;
- ➪ by the same date, the range of data that are captured and exchanged within NEAR-GOOS is expanded and the throughput increased, particularly in near real-time;
- ➪ a US National contributions to the Coastal module, along the lines outlined in section 4.6.5, is implemented.

Actions requiring continuation of existing funding or incremental enhancement

- ➪ maintain the existing programmes identified above, particularly where to do so adds to a long- term record, and is likely to contribute to the delivery of identified benefits;
- ➪ by agreement with the programme concerned, expand or modify their remit to better meet the needs of the GOOS end-users, e.g. by adding parameters to be monitored, improving QA procedures, varying working practices to improve long term stability of the record or improve the timeliness of data.
- ➪ enhance the capability of existing platforms, e.g. by equipping:
  - – meteorological buoys and platforms to make required sub-surface measurements;
  - – other fixed and drifting buoys with chemical and biological sensors;
  - – coastal ships of opportunity, such as ferries on useful, stable routes, to make automated marine measurements of variables and analytes to the required quality.
- ➪ expand geographic coverage of observing systems to data sparse areas,and to fill geographical gaps.
- ➪ in a concerted manner and to meet specific needs, adapt the roles of existing operational modelling centres to include marine modelling.

Continuing implementation, assessment and improvement of the ongoing GOOS

Implementation of demonstration projects for which there is widespread community support

- fully implement the three EuroGOOS projects relating to the Baltic, Mediterranean and NW Shelf seas.

Although the necessary funding has not yet been gained, if this can be achieved it would be helpful to initiate further regional initiatives during the next few years, particularly if these involve developing countries or countries in transition, and broaden the range of climates and management problem being tackled. The Black Sea Observing and Forecasting System (BSOFS) and BLACKMARS projects (6.5), SEACAMP and WIOMAP are regional projects that have distinct, attractive features in this regard. They have carried out or are in the process of completing the recommended pre-cursor actions.

A proposal has been made to establish a Med-GOOS to promote the implementation of the GOOS in the Mediterranean region (IOC, 1998c). Proposals are under consideration to establish a SEA-GOOS in South East Asia, and a Pacific-GOOS for the south-west Pacific.

It is likely that further demonstration projects will be proposed when the LMR and Coastal panels begin their work.

Where required, replication of proven techniques, capable of delivering quantified benefits
e.g. implement:

- storm surge forecasting and warning services, such as those provided by the UK and the Netherlands;
- buoy-based monitoring and forecast systems to serve the aquaculture industry.

Technology development priorities

these are recommended to be:

- development of automated biological and chemical sensors and specifically of methods to reduce the difficulty of measurement of the category 3 analytes identified by the HOTO Panel, viz. algal toxins, synthetic organic compounds, herbicides, pesticides and PAHs;
- creation of bathymetry datasets suitable for numerical modelling of the shelf.

Contributions to the International Conventions

- use relevant guidance provided by the HOTO and LMR modules to contribute to monitoring called for by the Agenda 21, Chapter 17 (3.1.6), the GPA/LBA (3.1.9), the Convention on Biodiversity (3.1.5) and the regional initiatives of HELCOM (3.1.10) and OSPAR (3.1.11).
- implement this theme to make a useful contribution to the next periodical survey of the marine environment,to be carried out by the GESAMP for 2002.

South East Asian Centre for Atmospheric and Marine Prediction (SEACAMP) Project

A project proposal has been developed (WMO/IOC, 1996) to establish, develop and coordinate long term meteorological and physical oceanographic monitoring, assessment, modelling and prediction capabilities of the ASEAN countries; it is known as the SEACAMP project. The objectives are to:

- **upgrade and/or establish oceanographic and meteorological observing stations in the region, to provide agencies with the data they require;**
- **create a regional centre capable of generating and distributing marine products to assist ASEAN countries meet their needs for services in support of disaster mitigation, environmental protection, resource management, industrial development, shipping and fisheries, pollution monitoring and climate monitoring and research;**
- **participate in the GCOS and the GOOS;**
- **develop capabilities in these fields;**
- **help ASEAN countries to fulfil their relevant obligations to implementation of Agenda 21.**

The project budget for a 3-year programme is some $11 million, with a run-on cost thereafter of some $3 million per annum.

Western Indian Ocean Marine Applications Project (WIOMAP)

A project similar to the above is under consideration by agencies serving a number of east African countries and island states in the western Indian Ocean. The objectives are to enhance operational marine services in the region, based on applied research and increased accessibility and exchange of relevant data. It is hoped to submit proposals for funding in the first half of 1999.

5.7.4 Theme 2 Implementation of global open-ocean monitoring and modelling

In what follows it should be borne in mind that the LMR panel has not yet finalised its plans; when it does so an additional set of priorities will emerge, to meet the needs of resource managers, that are likely to have an impact in this domain. At this stage, two strands of development based on open ocean monitoring and modelling can be identified: first, the continuing development and improvement of seasonal to inter-annual prediction and second, the GODAE initiative, that may contribute to the first in due course. Implementation of the GOOS here will make a significant contribution to the GCOS and priorities have been refined with that System.

Relevant highlights from the Conference on the WCRP held in August 1997 are germane and include:

- *Observation systems are under serious threat in several regions and they must be maintained and enhanced where necessary;*
- *More financial support and commitment should be given to the GCOS, the climate related aspects of the Global Atmospheric Watch and the climate components of the GOOS and GTOS;*
- *An operational ocean observing system for climate must be developed.*
- *Long-term, stable support must be provided for data management, information systems, analysis and re-analysis, quality control, archiving and distribution.*
- *Free and unrestricted access to all climate-related data for research purpose is vital to meet international obligations.*
- *Long-term historical datasets currently existing in non-electronic form should be rescued before they are permanently lost.*
- *Gaps in data-sparse areas must be filled.*

Existing Programmes

The legacy systems of TOGA and WOCE, such as the TAO array, the Japanese TRITON buoy programme and national programmes administered by the SOOP, the VOS, the GLOSS, the national buoy programmes coordinated by the DBCP, PIRATA, the GTSPP and the GTS are components of the GOOS-IOS that contribute to this Theme. In addition, the existing and planned programmes of the space agencies for remotely sensed data, the growing findings from WOCE, JGOFS and those expected from CLIVAR-GOALS, existing modelling efforts and the emerging IRI and CLIPS, provide a basis for further development of seasonal to interannual prediction.

The GODAE provides the focus for data assimilation and modelling. It will be highly dependent on support from all of the above. New technology will be needed to fill the geographical gaps in existing systems.

It remains to be seen whether it will be more attractive to reach an accommodation with and modification of the existing IGOSS/IODE and Argos to cover real-time data collection/distribution, to generate a new, improved infrastructure for the purpose or, most likely, some mixture of the two. In any case, new investment will be required.

Timetable

The timing of action in support of seasonal-to-interannual prediction will depend on the results of demonstrations in relevant research programmes, and the perceived benefits of maintaining the associated facilities on an operational basis.

More generally, the expectation that WOCE AIMS will deliver against its goals by 2002 is significant. By this time that community expects to have:

- quantified the main transport mechanisms controlling the global circulation – an important input to the design of a system set up to monitor that circulation;
- developed an ocean model which, when coupled with appropriate atmospheric and cryospheric models, is suitable for climate prediction;
- constructed a dynamically consistent data-base (atlas) of the general circulation of the oceans;
- begun to develop sophisticated data assimilation methods, for use in evaluating deficiencies in the above climate model.

It is expected that JGOFS synthesis and modelling will reach fruition by 2004.

As for Theme 1, the planned availability until at least 2005 of satellite missions capable of meeting the stated requirements for SST, sea state, ocean topography, sea level, ocean circulation and ocean colour measurements are highly relevant.

Alongside these programme milestones we have the inheritance of the immediate past in terms of technology and some expectations of the rate at which enhancements might occur for deployment in a range of programmes. Such considerations allow us to make proposals concerning the tried-and-tested technology of the PALACE floats and ATLAS moorings for example, and to be encouraged that acoustic tomography can be extended operationally in the next few years and that teraflop-terabyte powerful processors will be available by 2003.

Continuing implementation, assessment and improvement of the ongoing GOOS

The milestones set out above, that culminate in the GODAE in 2003-5, have led to suggested implementation of the experiment in 4 phases:

phase 1: 1997
- develop and gain support for the concept;
- produce the first version of an Experimental Plan;

phase 2: 1998/9
- develop an implementation strategy;
- entrain groups, agencies and individuals;
- begin establishing infrastructure;

phase 3: 1999-2002:
- test sub-components;
- conduct regional pre-cursor experiments and pilots;

phase 4: 2003-2005:
- carry out the experiment in a pseudo-operational manner.

This structure has been used in formulating the recommended priorities for action that follow.
The aim should be to build up investment in this theme through 1998 to 2003, in order to prepare for the GODAE and to make full use of the opportunity afforded by space agency investment in global ocean monitoring during the period to 2005. ***If benefits are not demonstrated as a result of such investment it is unlikely to be repeated. Given the lead-time of the space industry, some such benefits need to be apparent early in the period.***

Recommended actions
General

by the OOPC:

➪ *The advice available from the OOSDP, that has been clarified and updated by the OOPC, on the priority measurements, accuracy and sampling rates applicable to this domain should continue to be subject to refinement in the light of ongoing research and the detailed planning for the GODAE.*

by agencies capable of carrying out such work:

➪ *conduct of Observing System Simulation Experiments (OSSEs), based, in part, upon the most recent, well observed El Niño event, in order to assist in the optimisation of the observing system for seasonal to interannual prediction.*

➪ *exploit practical experience gained in operational programmes such as the TAO array to inform replication elsewhere.*

➪ *give priority to those* in situ *monitoring networks that complement the space component.*

➪ *The GODAE provides an important unifying framework for the concerted effort that is sought from both operational agencies and the research community, and should be embraced by those agencies able to make a contribution.*

Actions requiring continuation of existing funding or incremental enhancement

➪ *With immediate effect and in the light of available advice, define and seek contributions that are required to maintain and adapt existing programmes, from:*

a. the widest possible range of supply and coordinating agencies, such as National Meteorological and Oceanographic Services, DBCP, GLOSS, TAO IP, SOOP and CMM,:
   - those *in situ* observing systems which they provide, deploy and/or operate (e.g. VOS, XBT, PALACE, moored and surface drifting buoys);

b. the space agencies, individually and collectively within CEOS:
   - elements of their Earth observation and communication space programmes;

c. operational organisations, such as NOAA/GOOS, NOAA/NCEP, ECMWF, UKMO, BoM, JMA, FNOC, and IGOSS/IODE, input in the form of:
   - data communication, global modelling and archiving capabilities and practical knowledge of sound QA procedures.

5.7
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Continuing implementation, assessment and improvement of the ongoing GOOS

Item c. may not appear to have the immediacy of items a. and b. but until such data management/processing capabilities are put in place the full benefits of investment in observing systems will not be realised.

➪ *Typical incremental enhancement of the capabilities of observing systems within the GOOS might usefully include:*

a. the addition of new or improved sensors (e.g. acoustics and optics) to existing platforms (e.g. ATOC receivers to ATLAS and TRITON buoys)

b. providing operational support for the PIRATA after 2000;

c. other extensions of the TAO networks (e.g. into the Indian Ocean).

➪ *The continuation of measurements for which there is an important time series should be a high priority. Provided that the problem of aliasing is recognised in the design, such extension does not have to be continuous in time. Thus, periodic repetition of a particular route, hydrographic section or plankton survey for which there is a long record showing significant, perhaps unexplained, variance should be supported. Care has to be exercised in calibration to avoid temporal biases, but it is to be expected that improvements in measurement technology will be exploited. Particular emphasis should be given to 'choke points', where it is known that bottom topography or convection have a strong effect upon important flows. A number of these are located at high latitudes.*

Implementation of demonstration projects for which there is widespread community support

➪ *National and international projects in the WOCE, CLIVAR, JGOFS and GLOBEC programmes where these contribute to the objectives and principles of the GOOS;*

➪ *In particular during the period between now and 2002, regional monitoring and modelling projects such as those of EuroGOOS, focused on the Arctic and Atlantic, and the U.S. North Pacific project – see box – can make important preparatory contributions to the GODAE.*

Technology development priorities

➪ *High priority should be placed on the further development of technology in the fields of :*

- *acoustic thermometry and tomography,*
- *salinity measurements,*
- *profiling floats,*
- *Autonomous Underwater Vehicles,*
- *Acoustic Doppler Current Profilers for deployment by the VOS,*
- *more accurate discrimination of ice cover at the ice edge, where a mixture of open leads and solid ice prevails;*
- *anti-fouling methods, to increase the effective lifetime of automated instruments;*
- *optics and acoustics for biological measurements.*

Contributions to the Conventions

➪ *This Theme will make its most direct contribution to commitments made under the Framework Convention on Climate Change (3.1.4) but is also relevant to the London Convention (3.1.8) and the "Straddling Stocks" Convention (3.1.7). Contributions will be made indirectly to the Conventions listed under Theme 1.*

Monitoring the North Pacific for improved ocean, weather and climate forecasts

A proposal, being conducted under the National Ocean Partnership Program by a number of U.S. agencies, to monitor and model the North Pacific is indicative of the approach that is required. The project aims to describe and understand the evolution of that part of the Pacific, provide a sound basis for improved services and prepare for the GODAE. A partnership of NESDIS and PMEL of NOAA, the U.S Navy Naval Research Laboratory, the applied Physics Laboratory of the University of Washington and the Scripps Institute of the University of California is being formed to develop appropriate technology, collect data and assimilate them into numerical models. The domain for the work is the North Pacific because of its observed variability on decadal timescales and its significance for U.S. weather and climate. The project is archetypal in bringing together different institutions, albeit from one country, each with its own particular expertise, to carry out a full spectrum of activities necessary to develop capabilities and deliver improved services. Full use will be made of existing (sparse) observations. The additional observing suite combines remote sounding from satellites, *in situ* measurements from well instrumented moored buoys and the use of acoustic thermometry. One buoy is to be deployed to extend a long running data set at the location of Ocean Weather Station 'Papa'. The ocean circulation model will be eddy resolving and the project promises to develop an adjoint assimilation scheme.

5.7.5 Provision of structural support and expertise

A certain level of structural support and expertise is essential to facilitate the implementation of the GOOS and its two major Themes. As demonstrated in chapters 3 and 4, already substantial, widespread material and intellectual investment has been made in the foundations, planning, design and prototypical elements of the GOOS. These will not be brought together and enhanced to create an effective and efficient operational system without such support and expertise

The tasks can be characterised as:

a. the conduct of international planning and coordination that promotes and enables collective investment, particularly where there are cross-cutting issues to be resolved such as those of data management and the development of a consensus over space-data requirements;

b. ensuring the creation, maintenance and promotion of internationally acceptable operational procedures and practices;

c. facilitating training and other forms of capacity building, noting that this is not an optional add-on but a fundamental objective of the GOOS and essential in a global system being conducted under the terms of the UNCLOS and the UNCED.

Existing programmes/activities

The GOOS is fortunate in having sponsors with substantial existing experience and relevant programmes in these fields.

Thus WMO has carried out the above tasks in respect of operational meteorology for many years and has created appropriate planning, coordination, regulatory and advisory bodies accordingly. There is little doubt that the lessons learned and some of the existing bodies, such as the CMM, can be and are being adapted to carry out the equivalent tasks for the GOOS. Similarly, the WMO ‘Education and Training’ and ‘Technical Cooperation’ Programmes have useful lessons for capacity building and resource mobilization.

Whilst IOC does not have the same operational experience, its regional structures are constructed to reflect the realities of the oceans and seas of the Earth and the interests of the coastal and maritime States. IOC is also cosponsor of many of the scientific and technical bodies that are guiding development of the foundations of the GOOS. Its Committee for Training, Education and Mutual Assistance (TEMA) in the Marine Sciences, and its programmes have much to contribute in these fields within the GOOS.

UNEP has relevant experience and expertise gained, for example, in its Regional Seas programmes, as the Secretariat for the GPA/LBA and as one of the three GEF Implementing Agencies.

Similarly, the ICSU provides ready access to a wide range of international scientific programmes of relevance to the GOOS, including but not limited to those cited in section 3.4. The START initiative of three of these – the HDP, IGBP and WCRP (3.4.3) – was designed to build the indigenous capacity of developing regions of the world to participate in the various global change research scientific agendas. ICSU has its own Committee on Capacity Building in Science.

Whilst it is reasonable to expect the funding of operational activities to be provided through appropriate agency budgets and for science programmes through national science foundations, the funding of support function is less direct. In effect, tasks (a) and (b) are overheads on the operational and research functions that they help to sustain, justified on the basis of the economies of scale and cost sharing, and hence cost saving, that they enable. Task (c) is likely to be funded through national and international development aid organisations, including the World Bank and the Global Environmental Facility (GEF).

The GPO, GSC and its Panels, JDIMP, GOSSP, and regional programmes such as EuroGOOS and NEAR-GOOS, are in place and well able to provide advice within their TORs and mandates (annex 2). However, these can only be as effective as national contributions in the form of funding, seconded experts and representation permits.

5.7
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Continuing implementation, assessment and improvement of the ongoing GOOS

Timetable
This is an ongoing function whose pace of development will be limited by the availability of resources.

Recommended actions
In most cases, the lead is self-evident or specified, but generally these are directed to a combination of the sponsors, the G3OS planning offices and appropriate operational and aid agencies. Funding is vital, but unless experienced, able people are committed to tasks, often by the operational agencies, value for money will not be achieved. The role of the sponsors and planning offices is to play an active role targeting the material and financial resources, based on their experience and knowledge of regional needs and capabilities.

Actions requiring continuation of existing funding or incremental enhancement

With respect to (a), international planning and coordination (b) operational methods:

- *It is important that the implementation of the GOOS continues to be based on the best current scientific and operational advice available in relevant disciplines. The GOOS panels provide one method of achieving this and should meet to address specific problems identified by the GSC. Their effectiveness will be increased if members are practising experts in their fields. Specialist coordination groups such as the TAO IP, SOOP, DBCP and relevant CMM working groups are a source of operational expertise that should be utilised.*

- *After the LMR panel has completed its basic task, consideration should be given to simplifying the panel structure to reflect the thematic structure of this Implementation Framework.*
- *The G3OS panels, JDIMP and GOSSP, have important roles to play in generating broadly based advice in their respective cross-cutting fields and concerning the implementation of the IGOS. However, it is inevitable that execution of that advice in detail will take place at the level of individual projects and the panels should encourage such migration.*

With respect to (c), capacity building:

- *As a minimum, the existing level of investment in TEMA functions targeted upon the GOOS must be maintained.*

Replication of proven techniques capable of delivering established benefits

With respect to (a) and (b):

- *A G3OS Information Centre, based upon the successful Data information Units of the WOCE and TOGA Coupled Ocean-Atmosphere Circulation Experiment, has been proposed - see box. Such a centre is an inevitable corollary of a distributed data management system and its formation is recommended.*
- *to encourage adoption, within the GOOS, of all of the recommendations of the JDIMP and GOOS scientific panels concerning a distributed Data and Information System (DIS) based on a hierarchy of local, national, regional and global institutions, it is proposed to establish a Data and Information Management Service (DIMS) to:*
  - *promote and coordinate implementation of the recommendations within the GOOS on a day to day basis, working closely with the G3OS Information Centre;*
  - *facilitate negotiations between such institutions and existing oceanographic observing systems and programmes. These are expected to include but not be limited to the IGOSS, the GTSPP, the DBCP, the IODE, the GLOSS and the CEOS.*

Experience in WOCE and TOGA suggests that a Data Coordinator will need to be appointed for these purposes and to assist in the provision of the practical assistance to developing countries referred to below. He/she will be most effective if located in an active operational centre.

With respect to (c):

- *Regional workshops, organised by the GOOS ad hoc panel on capacity building, have been held in Goa, Mombassa and Malta. The first and third focused on awareness building and priority setting, the second on the preparation of a 5-year science plan for the coastal zone. Follow up on the recommendations of those workshops and their replication in other regions, based on an appreciation of the current capabilities of those regions, is recommended.*

Continuing implementation, assessment and improvement of the ongoing GOOS

A Global Ocean Observing Systems Information Centre

The JDIMP has proposed setting up a Global Ocean Observing Systems (G3OS) Information Centre to provide access to a distributed directory of data and information. Such a central source will provide basic user services that explain the G3OS data system and provide an overview of what data and information are available. In addition, the Information Centre will offer a search capability, optimised for G3OS data centres, and thereby facilitate access and links to a world-wide set of observations and derived products.

Though the exact technical nature of the system has not yet been defined, such a system is expected to:

- **Conduct a search for data information across the Internet and all participating data centres, including the World Data Centres.**
- **Return results regardless of the data format, or where the data are located.**
- **Provide results back in a standard easy-to-read, easy-to-understand format.**
- **Allow users to determine the type and quality of the data through documentation provided by the participating data centres.**
- **Allow users to obtain datasets. (If data exist but are not available for distribution, that fact should be communicated as early as possible in the search procedure.)**

The Information Centre will not be a repository for data nor a mechanism for accessing real-time data. Rather, it will maintain a database of information about the datasets that are available in the three programmes and will point to the data centres where the data may be obtained. The Information Centre will not create or modify the presentation of data. To the extent that it is possible, with overlapping data collections, the programmatic source of data and information will be identified.

In addition to data, the Information Centre will also provide access to information, in the form of summaries, charts, climate trends and indices, and documents. Though nearly all of this material will be developed at data centres or by researchers, the Information Centre will provide an initial access and, in addition, will prepare summary information to provide an overview of what is available to users.

A pilot Information Centre, is to be established at the College of Marine Studies of the University of Delaware, USA, which has experience of setting up and operating the broadly equivalent WOCE and TOGA Data Information Units.

➪ *A number of courses exist to providing training relevant to the GOOS, within NEARGOOS and GLOSS for example. Replication within other relevant programmes is recommended.*

➪ *The DIMS should provide practical assistance to developing Member States to identify and gain access to appropriate data sets, facilitate their contribution to those data sets and demonstrate how these, either alone or in combination with others, may be turned intoservices and products valuable to local users.*

➪ *The regional implementations of the EuroGOOS, NEAR-GOOS and perhaps U.S. GOOS are 'locomotives' that are capable of advancing similar implementations in developing countries through partnerships at the individual, agency and institute level. Practical efforts to establish the necessary coupling are required. A EuroGOOS Forum, held in Toulouse in 1997, on the subject concluded that:*

– *The EuroGOOS provides an appropriate structure for capacity building, but to be effective this has to be embedded in individual projects .*

– *There are potential benefits for the EuroGOOS in capacity building in the form of access to important information and markets.*

– *Action should be targeted on countries and regions that have at least a threshold capability.*

– *The capacity building that could be offered centred on training in awareness and operational methods.*

➪ *The example of the Black Sea demonstrates the importance of investment in infrastructure as well as training; in that case by the EU, GEF, NATO and individual countries. The example should be followed.*

5.7
A FRAMEWORK FOR IMPLEMENTATION – PRIORITIES FOR ACTION

Continuing implementation, assessment and improvement of the ongoing GOOS

Development priorities

With respect to (a) and (b):

➪ *Under the leadership of the sponsors, the negotiation and adoption of a data policy that formalises the aspiration of principle D7 in section 1.4 is a high priority.*

➪ *The benefits of investment in the GOOS are not getting through to the public and governments; a campaign to correct this is essential, building on the ability and connections of a few individuals to get the message across. The message should be based on:*

- *the scientific, technological and legal foundations;*
- *the economic benefits;*
- *the commitments made in existing Conventions.*

With respect to (c):

➪ *Capacity building is not simply a matter of replicating a tried and tested formula. Each case is different and competing for finite aid or venture capital. The creation of innovative and persuasive individual proposals is essential therefore. Further development of methodologies for this in and by the marine community is an important task to be pursued, under the leadership of the sponsors.*

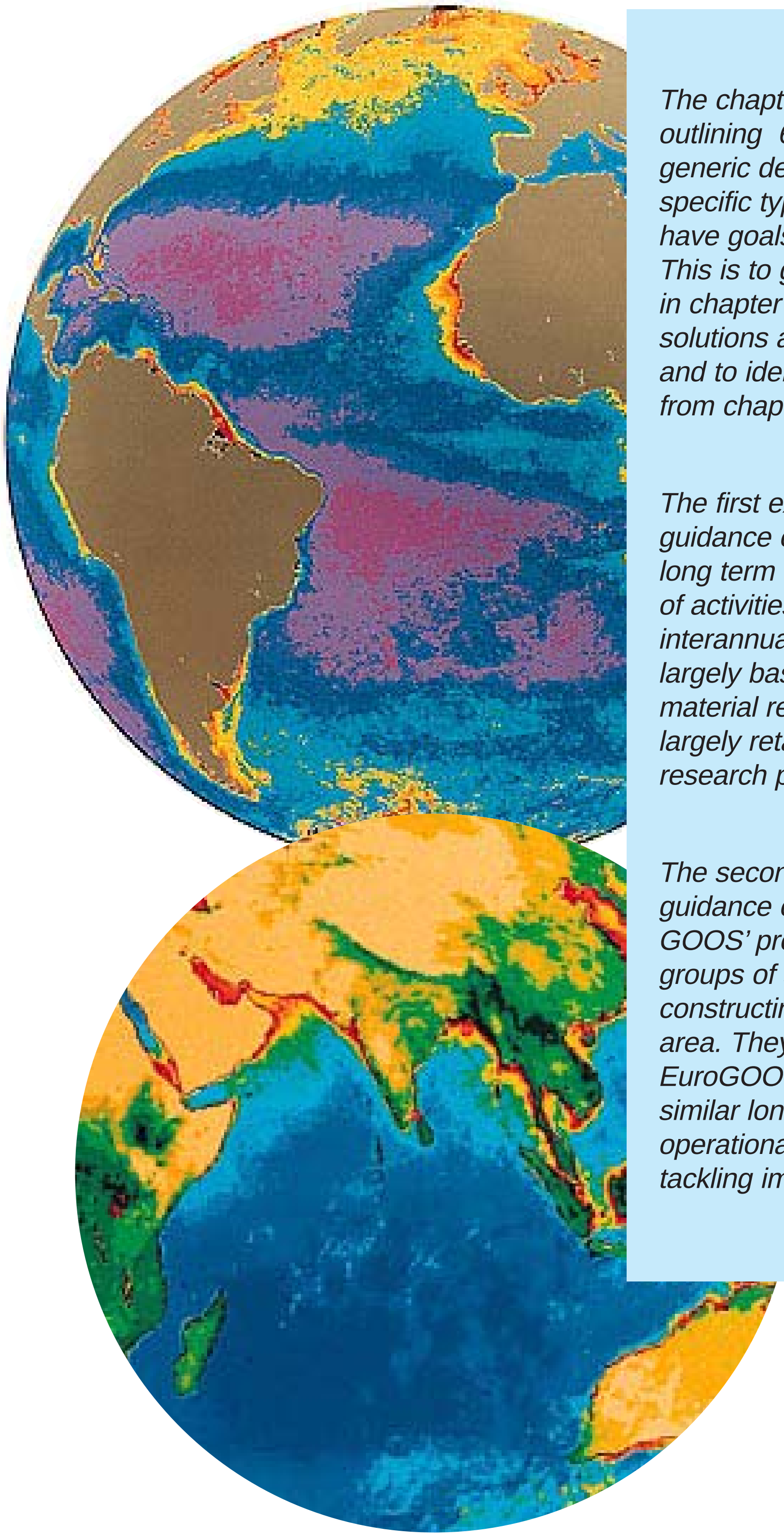
Specifically:

- Although section 3.3.3 has pointed out the difficulties in carrying out CBA in support of the GOOS investment proposals, considerable benefits to capacity building would follow from their solution and then application in the case of projects in developing countries, seeking GEF funding for example.
- The connectivity between investment in data capture, QA and exchange and the delivery of products and services of value to developing countries needs to be demonstrated.

5.7.6 Concluding remarks

No attempt is made finally to prioritise implementation of the two themes. It seems likely that local and regional priorities will provide sufficient focus to ensure that the GOOS progresses in line with need in the coastal/shelf domain. However active and far-sighted support needs to be given to efforts in the open ocean domain, in particular to the unifying proposal of GODAE, because of their importance in capturing the data required to understand and predict climate on timescales beyond the seasonal and the extension of the predictability of local and regional services. Support for the unglamorous activities that ensure efficiency in planning and operation of a highly distributed GOOS and facilitate the associated capacity building in developing countries are also vital to achieve the global goal and the full set of objectives.

6
PROTOTYPE OBSERVING PROGRAMMES



The chapter tests the design concept by outlining 6 programmes that illustrate the generic design of chapter 4, are targeted upon specific types of management problem and have goals to build the required capabilities. This is to give reality to the general discussion in chapter 4, to reinforce the point that solutions are ultimately problem specific and to identify any lessons to be learned from chapter 5.

The first example, that provides us with guidance on the development of medium to long term forecasting systems, is the collection of activities that provide seasonal to interannual predictions of climate. These are largely based on the insight gained and material resources put in place and then largely retained as a result of the TOGA research programme.

The second and third examples provide us with guidance on the development of regional 'mini-GOOS' programmes of the kind that enable groups of states to pool their resources to start constructing the GOOS in their immediate area. They comprise the regional initiatives of EuroGOOS and NEAR-GOOS and have similar long-term objectives to provide operational oceanographic services, but are tackling implementation in quite different ways.

6
PROTOTYPE OBSERVING PROGRAMMES

Introduction

The fourth provides guidance on the management of coastal ecosystems in the GOOS context. It is taken from an actual programme to establish why a particular ecosystem (the Black Sea) was being degraded and what action needed to be taken to begin to rehabilitate it. This started before the GOOS began to be implemented but is symptomatic of the sort of management problem for which the GOOS might be expected to provide valuable information services.

The fifth is also concerned with a coastal ecosystem – that of the SADC countries, which border the Benguela current in the South Atlantic. Here there is prima facie evidence of environmental impacts on important fisheries, but without reliable information, scientific understanding, and the appropriate policy, legal and institutional infrastructure, it is not possible to take effective action to achieve sustainable development. The steps being taken to correct these deficiencies are instructive.

The sixth illustrates the development of a technology demonstrator project designed to test how in situ *and remotely sensed data from space can be integrated and assimilated into ocean forecasting models on the global scale. It applies the work of the OOSDP and the emerging results of WOCE, to a specific experiment, GODAE, that is likely to reach fruition in the period 2003 – 2007.*

6.2 Seasonal to Interannual Prediction of Climate

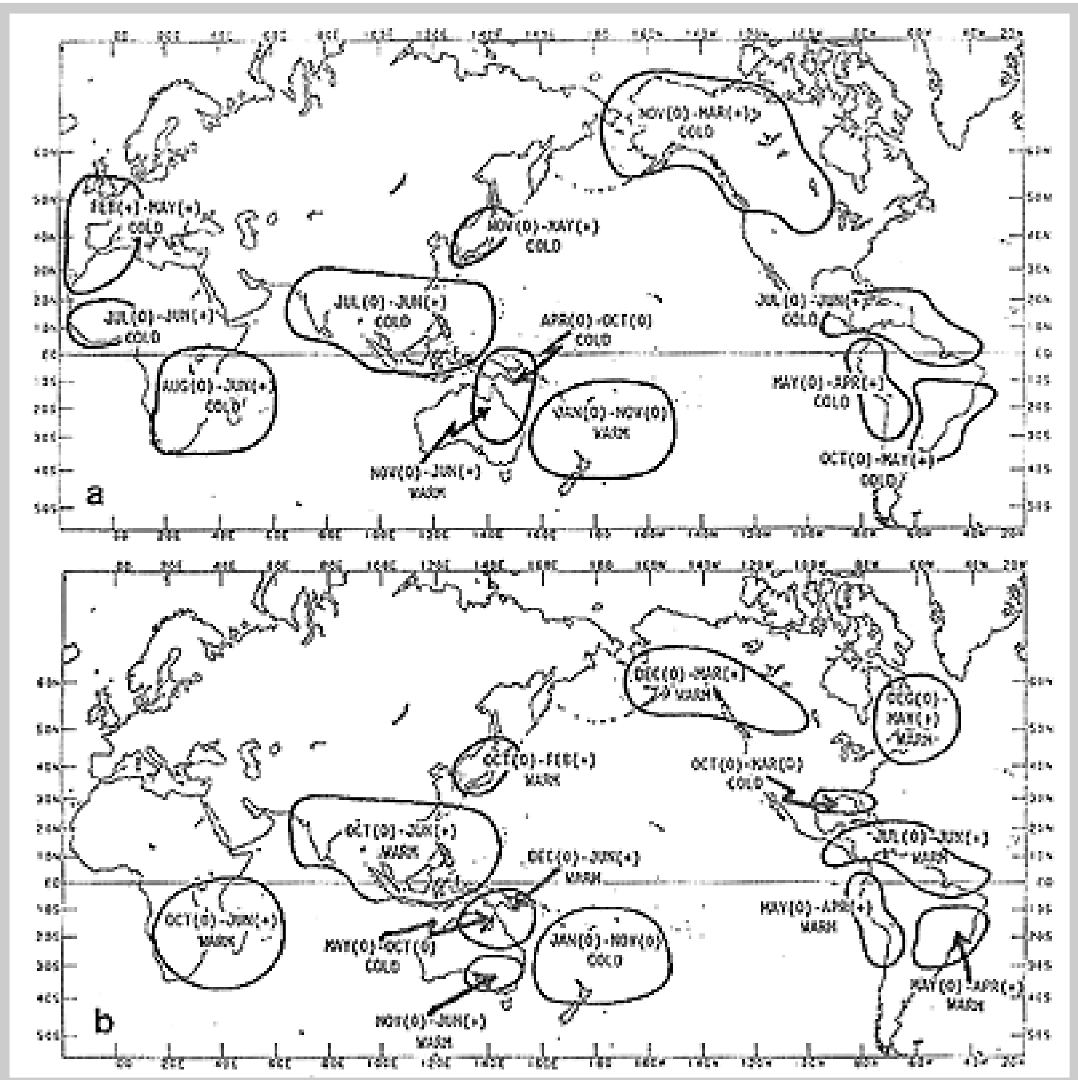
Scientific basis

The principal scientific basis of seasonal to interannual prediction of climate is founded on the premise (see, for example, Palmer and Anderson (1994) and Carson (1998)) that lower-boundary forcing, which evolves on a slower timescale than that of the weather systems themselves, can give rise to significant predictability of atmospheric evolution. These boundary conditions include SST, sea-ice cover and temperature, land-surface temperature and albedo, soil moisture and snow cover, although they are not all believed to be of equal importance. Variations in lower-boundary conditions result, in part, from the coupling of the dynamics of the atmosphere to the dynamics of the oceans and to the hydrology of the land masses, so there is an element of feedback.

The strongest evidence for long-term predictability comes from the influence of persistent SST anomalies on atmospheric circulation that, in turn, induces seasonal climate anomalies. The most well-known of these are related to the ENSO coupled ocean-atmosphere phenomenon in the tropical Pacific Ocean (see, for example, Allan et al. [1996]). The fact that the tropics are inherently more predictable on the seasonal timescale, than mid latitudes for example, is thought to derive from the fact that the internal chaotic variability of the large-scale tropical atmosphere is relatively weak. Much of the variability of the extratropical atmosphere and oceans is directly associated with internal instability and non-linearity.

The ENSO phenomenon is also strong because there is positive feedback in the coupling. It appears that equatorially trapped planetary-scale waves in the ocean (Kelvin and Rossby waves) are responsible for setting the time scale of events of a few years.

ENSO is correlated with many climate anomalies around the globe, both within and outside the tropics – see for example Halpert and Ropelewski (1992).



Schematic representation of regions that show a strong correlation with (a.) high (b.) low SO index.

The time of year when the correlation is strongest is shown wiithin the region. The symbol '0' denotes the same year as the peak of the SO; '+' denotes the following year.

Seasonal to interannual prediction of climate

Current capabilities and services

Barnston et al. (1994), provided a comprehensive review of capabilities in ENSO forecasting, as they stood in the mid-nineties. They describe five distinct operational ENSO forecast systems, that continue to be representative of the different methods in current use. They demonstrated that a moderate level of mean skill was possessed by all of the methods of forecasting tropical Pacific SST, with correlation skill averaging in the 0.60s with a lead time of 9 months, and a more modest but statistically significant capability with a lead time of over a year. This suggested that the empirical and physical models had captured the essentials of interannual ENSO variability. However, the skill of any of the methods varied markedly over time about its average. Furthermore, within the range of statistical uncertainty, the overall skills of all the methods were equal. This implies that, at that time, the three physical models did not significantly outperform the two empirically based models. If the ocean-atmosphere system contains sufficient inherent predictability, the dynamical models should be able to clearly outperform models that do not use the equations of physical oceanic and atmospheric motion or cannot accommodate non-linearity.

Recorded impacts to date of the 1997 ENSO – NOAA Web Page

Drier than normal:

- Indonesia/eastern Australia/New Guinea/southern part of west Africa: very dry since June, with large-scale wildfires and drought.
- Central and northern South America; Alaska;

Wetter than normal:

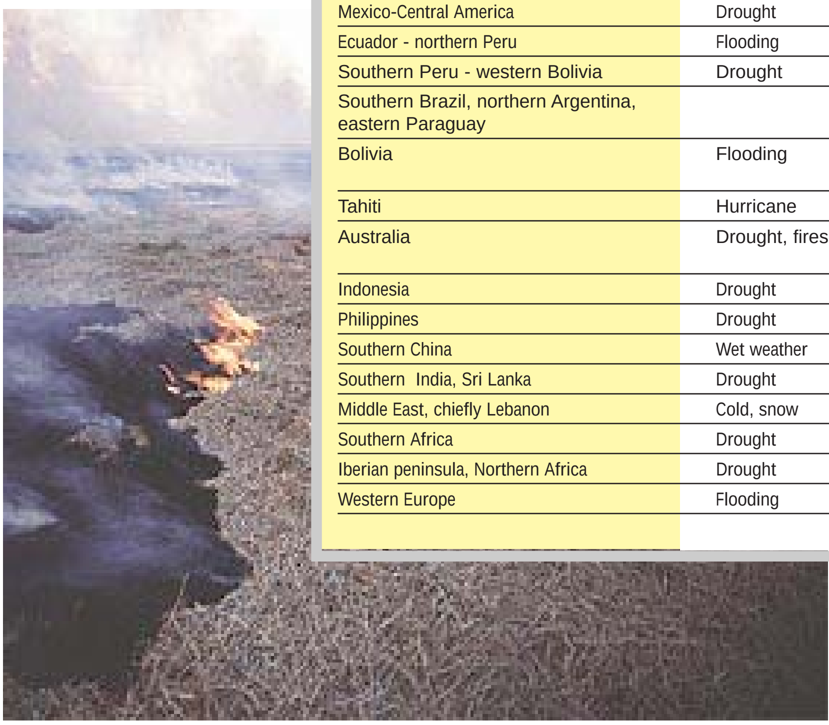
- Southern South America, with central Chile getting its normal annual rainfall in a single day.
- Ecuador, northwest Peru, southwest Colombia, California, Texas and Florida.
- Equatorial east Africa: experienced heavy rainfall, 600-800mm above normal in parts of Kenya.

Unusual Conditions:

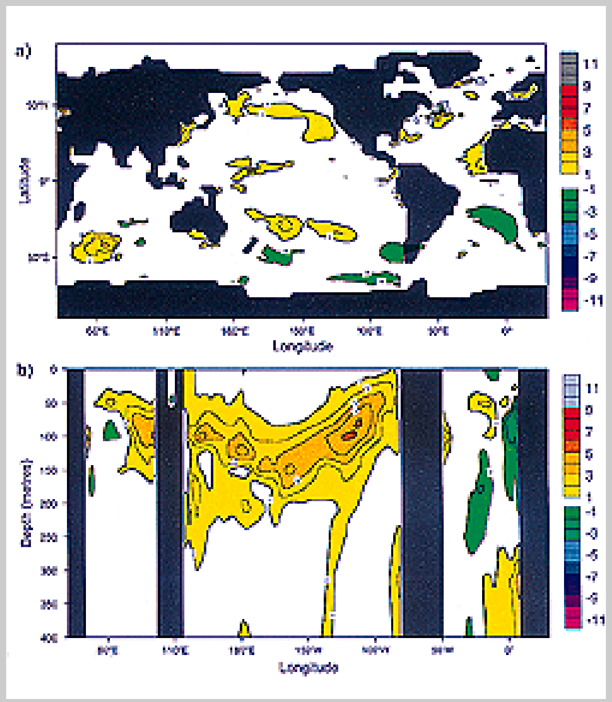
- North American west coast: abnormally warm waters associated with appearance of unusual marine species
- Eastern North Pacific: expanded area of favourable conditions for tropical cyclones
- Atlantic North America: substantial reduction in hurricane activity.

World-wide effects of the 1982-1983 ENSO
(source: The New York Times, 2 August 1983)

Location	Phenomena	Victims	Damage (billion US$)
US Mountain and Pacific States	Storms	45 dead	1.1
US Gulf States	Flooding	50 dead	1.1
Hawaii	Hurricane	1 dead	0.23
North-eastern USA	Storms	66 dead	-
Cuba	Flooding	15 dead	0.17
Mexico-Central America	Drought	-	0.6
Ecuador - northern Peru	Flooding	600 dead	0.65
Southern Peru - western Bolivia	Drought	-	0.24
Southern Brazil, northern Argentina, eastern Paraguay		600,000 evacuated 170 dead	3.0
Bolivia	Flooding	26,000 homeless 50 dead	0.3
Tahiti	Hurricane	1 dead	0.05
Australia	Drought, fires	8,000 homeless 71 dead	2.5
Indonesia	Drought	340 dead	0.5
Philippines	Drought	-	0.45
Southern China	Wet weather	600 dead	0.6
Southern India, Sri Lanka	Drought	-	0.15
Middle East, chiefly Lebanon	Cold, snow	65 dead	0.05
Southern Africa	Drought	Disease, starvation	1.0
Iberian peninsula, Northern Africa	Drought	-	0.2
Western Europe	Flooding	25 dead	0.2



Seasonal to interannual prediction of climate

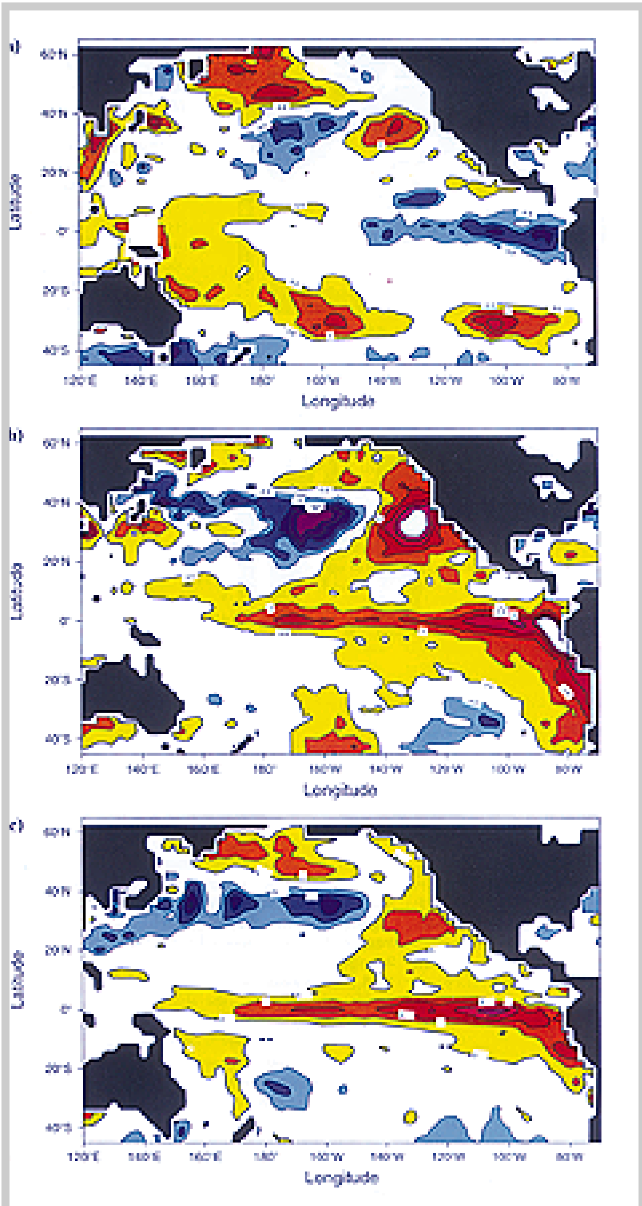


Although little or no temperature anomaly is observable at the sea surface in March 1997 (a), the vertical section along the equator at this time reveals a significant thermal anomaly of up to 5^{0}C 100 metres below the surface (b), demonstrating the importance of sub-surface data for characterising ENSO. (ECMWF, 1997)

Contour interval is 1^{0}C.

ENSO is not the only skilful predictor for seasonal and longer lead-time forecasting. For example, correlation between SST anomalies and local rainfall series in the tropics forms the basis of a number of experimental forecast services provided by the UK Meteorological Office, e.g. Ward and Folland (1991) and Folland et al. (1991). Typically, such forecasts use persistent SST anomalies for 1-3 months before the main rainfall season to predict the rainfall total for that season. For NE Brazil, ENSO plays a significant but not the dominant role in the statistical prediction scheme. Indeed, the NE Brazil forecasts use SST 'modes' in the tropical Atlantic and the whole Pacific. In contrast, the tropical N African forecasts combine world-wide 'modes', with particular focus on tropical Pacific and Atlantic anomalies and inter-hemispheric differences.

Driven in part by the well observed, substantial El Niño event that began in 1997 and the success of comprehensive coupled ocean-atmosphere models in predicting its onset, there is considerable interest and activity in seasonal and longer lead-time prediction of climate. The latest versions of the above and similar predictive methods are outlined, together with digests of their recent performance and future prognoses, in the Experimental Long-lead Forecast Bulletin, issued quarterly by the CPC of the NCEP, US National Weather Service, NOAA. The U.S. forecasts are also contained in the official Climate Outlook. Both the Bulletin and Outlook are available freely on the Internet with address: http://nic.fb4.noaa.gov. Preliminary estimates show that the 1997 El Niño caused many hundreds of millions of dollars of damage, but some of this was minimised by the advance warning.



Demonstration of the predictability of SST in the Equatorial Pacific (ECMWF, 1997)

a) Observed SST anomaly in December 1996
b) Observed SST anomaly in May 1997
c) Predicted SST anomaly for May 1997 based on forecasts initiated from December 1996 data.

Contour interval is 0.5^{0}C

6.2
PROTOTYPE OBSERVING PROGRAMMES

Seasonal to interannual prediction of climate

Climate Information and Prediction Services

To complement the CLIVAR research programme, the World Climate Applications and Services Programme (WCASP), another of the four major components of the World Climate Programme, is developing the Climate Information and Prediction Services (CLIPS) project. This is designed to foster practical applications of climate information and forecasts.

CLIPS was endorsed by the Twelfth World Meteorological Congress in June 1995 and included in the WMO Long-term Plan for 1996-2005. It is directed at one of four major thrusts (‘Climate Services for Sustainable Development’) of The Climate Agenda, the overarching framework for international climate-related programmes endorsed by eight international organizations led by the WMO. The objectives of CLIPS are:

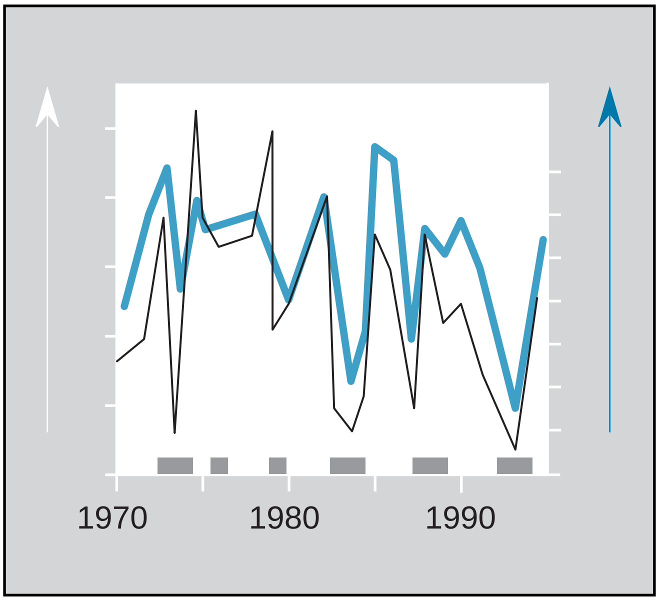
a. to provide an international framework necessary to enhance and promote climate information and prediction;

b. to facilitate the development and strengthening of a global network of regional/national climate centres, including communications and training; these centres will act as a focus for the provision of climate information and prediction services;

c. to demonstrate the value and eventual socio-economic benefits of climate information and prediction services, and the connection of those benefits with global observing, monitoring, prediction and applications;

d. to encourage the development of operational climate predictions for periods and regions that are feasible and directed towards useful, user-oriented applications.

The CLIPS Project is at a relatively early stage of its development; the components of its implementation are described in WMO (1997).



DROUGHTS AFFECT ZIMBABWEAN MAIZE YIELD

Maize yield

Rainfall

El Niño events

The International Research Institute for Climate Prediction

The concept of an International Research Institute for climate prediction (IRI) emerged around 1989 from a general consensus in the international climate research community involved in the TOGA project. It was argued that experimental forecast information could only be valuable if an institutional mechanism was in place to continually advance research and modelling related to the forecast capabilities, to disseminate forecasts on a routine basis, and to provide a centralised location for feedback on model results. The USA has taken the lead in designing such an institute for experimental short-range climate prediction. A key initial aim was that this would employ the scientific knowledge being developed about ENSO and work with the most affected countries to learn how to use these forecasts (see, for example, NRC [1996]). It was expected that the IRI would focus mainly on the prediction and applications, whilst drawing on observation systems such as the GOOS and process research programmes such as those of CLIVAR.

The intention is that the IRI should provide an international structure that combines world-wide research capabilities, operations and applications expertise. To this end, a multi-national Core Facility and a wider international Network of associated institutes are envisaged. The three main basic functions of the Core Facility are: research and development, experimental forecasting; and, applications and training. At the ‘input’ end, the Network would consist of independent climate and modelling groups linked to the Core, all accessing data from the GOOS and other members of the G3OS as necessary. Whereas, at the ‘output’ end, the interfaces between the Core and Network would include regional application networks and research institutes with ‘operational’ activities and responsibilities, probably shared through the involvement of the CLIPS project and local National Meteorological Services. In 1996, the initial IRI Core Facility was established jointly at the Lamont-Doherty Earth Observatory of Columbia University and the Scripps Institution of Oceanography, University of California.

Training individuals in the nature and use of prediction systems, provides the opportunity for developing countries to benefit specifically from research and applications training, as well as the dissemination and use of the climate forecasts themselves. The results relating to the forecasting of Zimbabwean maize yield, reported by Cane et al. (1994), are indicative of the approach. A study involving the Lamont-Doherty Earth Observatory and the Food Security Unit of the Southern African Development Community showed that maize yield in Zimbabwe and rainfall are closely correlated with contemporaneous rainfall are closely correlated with contemporaneous ENSO-related SST anomalies in the region of the Pacific bounded by 90° – 150°W, 5°S – 5°N. Prediction of those anomalies, by the methods described above, provides a forecast of maize yield as much as a year ahead. As a minimum, such forecasts should allow more efficient relief efforts in future; better planting decisions, as concerns both timing and crops, will be possible.

Future developments

- **Relevant research programmes**

Research is underway in both nationally and internationally coordinated programs whose primary goal is to improve the quality and extend the scope of seasonal to interannual prediction and also increase predictability to decadal timescales. The CLIVAR research programme of the WCRP, described in section 3.4.2, provides the international framework for this work on behalf of climate prediction. Efforts to improve the skill of ENSO forecasts are ongoing. There is also considerable interest in coupling between the large scale North Atlantic oceanic and atmospheric circulations on decadal timescales, possibly linked to the atmospheric North Atlantic Oscillation (NAO), Dickson et al. (1996), Dickson (1997), Sutton and Allen (1997). Chang et al. (1997) have suggested a positive atmosphere-ocean feedback to explain the observed decadal variation in the trade winds and the SST gradient across the equator in the Atlantic, the so-called Atlantic SST dipole. The variability of the North Pacific Ocean SST is exceeded only by that of the tropical Pacific, Harrison and Larkin (1997), and a US national programme to monitor and model the regime has been proposed. Such a sustained programme would make a substantial contribution to the GOOS.

Significance and implications for the GOOS

The role of the oceans, as the long term memory of the Earth system, emerges clearly from the above, as does the rationale for emphasis on observation of the tropical oceans as the basis for effective seasonal to interannual prediction. Sufficient is known now, however, to be confident that ***observation and modelling of the atmosphere and oceans beyond the tropics will be necessary to deepen understanding and extend predictability beyond the current limits.***

The above also ***provides an excellent example of the paradigm for the GOOS that has been outlined in chapter 4;*** reliable long-term observations of meteorological and oceanographic properties, together with focused, hypothesis-testing process research, enable the creation of basic products, from which valued services can be generated, tailored, promoted and made available to end users. ***In order to provide the compelling economic case (3.3.3) for the investment in observations and the other components of the service, all have to be in place to some extent. Because they cannot all be present at the outset, some risks have to be taken, not least in creating and maintaining the long-term record as the basis of empirical modelling and the testing of hypotheses.*** The emerging scientific understanding, that follows from their evaluation against the record, enables subsequent investment to be focused and more cost-effective. The example also demonstrates the importance of international co-operation both in research and operations. The proposals for the IRI and CLIPS illustrate the importance attached, at senior levels in governments and in agencies, to exploiting investment made in infrastructure and scientific advances through to applications.

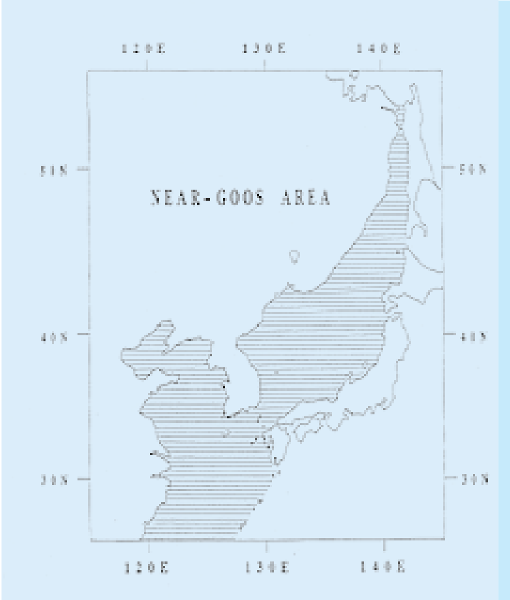
6.3 North - East Asian Regional GOOS (NEAR-GOOS)

NEAR-GOOS is being implemented by China, Japan, the republic of Korea and the Russian Federation as a WESTPAC project. It is intended to provide an operational demonstration of the usefulness of a regional ocean observing system in the achievement of its own specific goals and as a pilot for other parts of the world. The regional seas of the North East Asian Region have been chosen for this because of the available capacities of the countries involved to collect and exchange oceanographic data in real or near real-time. The region is one of the most densely and frequently surveyed areas in the world. The oceanographic data for NEAR-GOOS are temperature, salinity, currents, waves, sea-level, dissolved oxygen, nutrients, and other hydrographic elements.

The specific goals of the project are to:

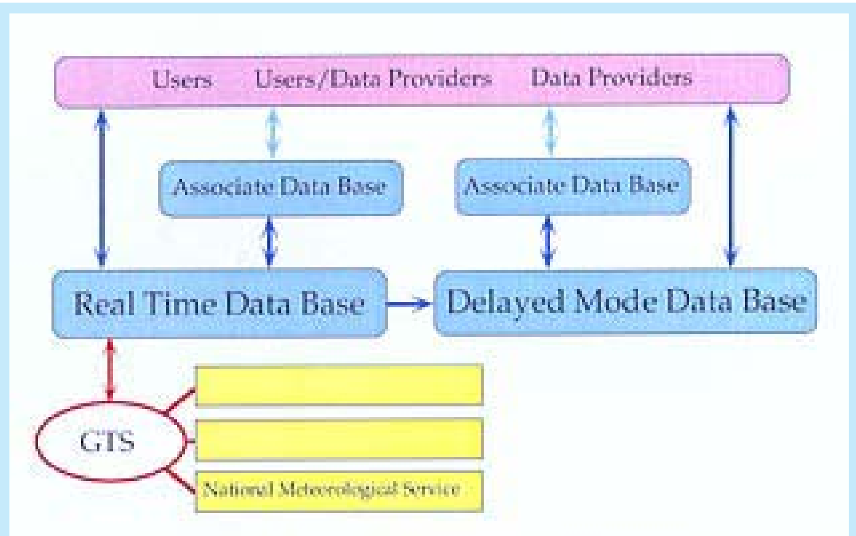
- improve ocean services in the region;
- provide data and information useful in the mitigation of the effects of natural disasters caused by waves, storm surges and sea ice;
- increase the efficiency of fishing vessels;
- provide information useful in pollution monitoring;
- monitor parameters useful in mariculture, particularly with regard to harmful algal blooms;
- provide information on the health of the coastal zone for recreational purposes;
- to provide data sets required for data assimilation, modelling and forecasting.

The first task of NEAR-GOOS has been to establish an efficient data exchange scheme for the existing observing systems in the region. The initial objectives were to establish a real-time database (RTDB), containing data from the past 30-days, and a delayed-mode database (DMDB) that contains all other data.



Data are input from the GTS and other sources. The RTDB and DMDB are maintained and operated by the JMA and JODC respectively. Associated Databases are installed by other countries in the region. Access is free of charge to all users, and established via the Internet. Initially QA/QC is the responsibility of contributors but a more comprehensive data management system will be developed. An Operation Manual defines, in detail, the operation of the data exchange system and user registration. An Implementation Plan for the Initial Phase of NEAR-GOOS has been published.

The coupling between data assimilation and analysis systems, and atmospheric and ocean general circulation models that are in operational use at the JMA are shown below. These, together with the DMDB, perform the archival, assimilation and modelling functions outlined in Chapter 4 but demonstrate that practical implementation is complex, sequential and physically distributed.



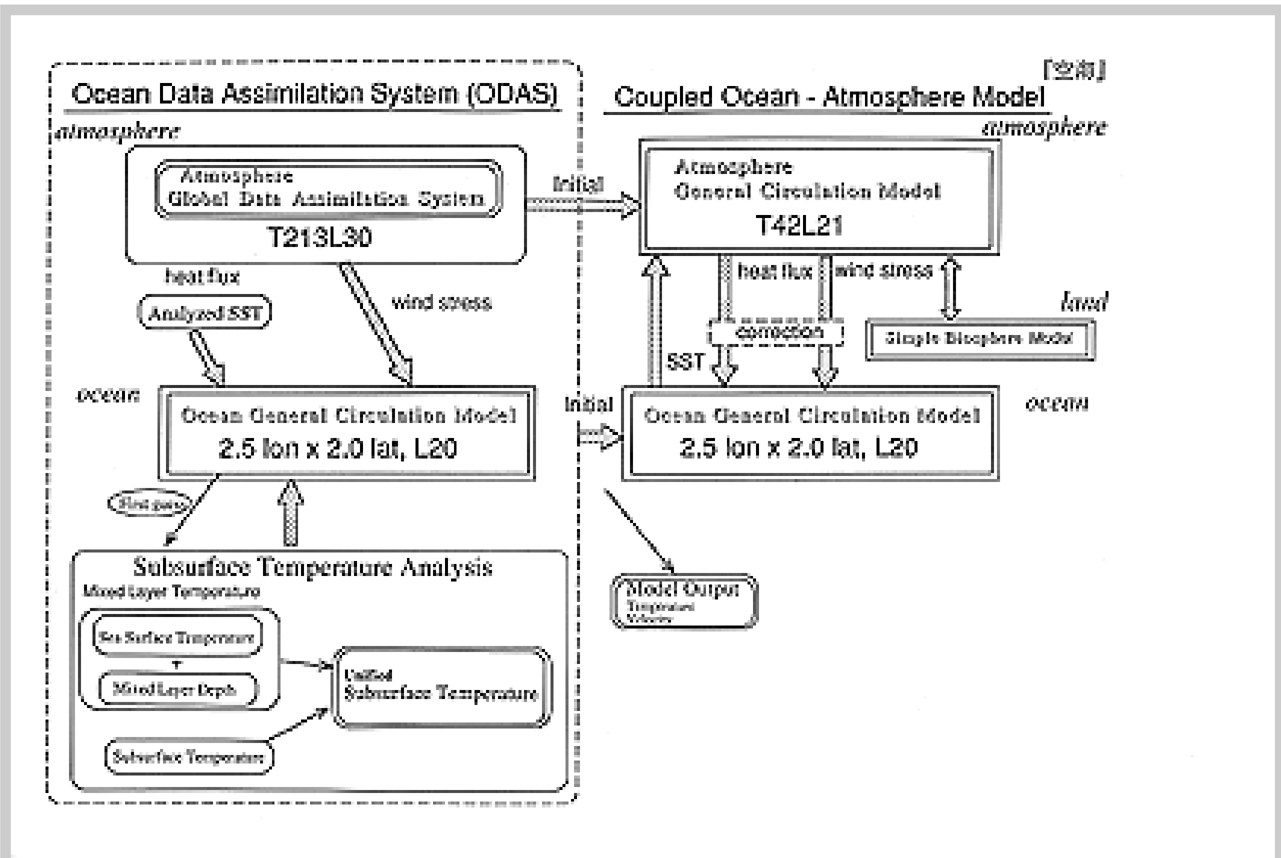
Data Flow in the NEAR-GOOS Data Exchange System

Significance and implications for the GOOS

It is notable that ***the NEAR-GOOS has been designed and is being implemented in the context of the IOC WESTPAC regional structure, as a result of agreement established at intergovernmental level.*** This is in contrast to the interagency agreements that sustain EuroGOOS, described below. It is also significant that ***the participants have chosen to establish an effective data management system as their first priority.*** This reflects the fact that the NEAR-GOOS area is one of the most densely and frequently surveyed maritime areas in the world and is heavily used. Therefore there is a substantial demand for services and a considerable amount of information is collected, although not all of it is available for widespread use. Furthermore ***the participants are heavily committed to the exchange of technology and expertise; data management provides many opportunities for this.***

In keeping with the GOOS principles, the resulting system is making maximum use of and building upon existing capabilities. Nevertheless, the opportunity to make full use of modern communication methods based upon the Internet has been seized. Such an approach has inevitably resulted in a highly distributed implementation.

The NEAR-GOOS is providing a most important model for other regional manifestations of the GOOS to learn from and adapt to their own circumstances.



6.4 EuroGOOS

The European Association for the Global Ocean Observing System (EuroGOOS) was formed in December 1994. It was set up to maximise the benefits to Europe from operational oceanography within the framework of the GOOS. Members of EuroGOOS are agencies who share a common set of goals and aims. They are committed to work together under the terms of a Memorandum of Understanding.

The goals are:

1. To gain the benefits from the last 50 years of investment in marine science and technology in Europe.
2. To create new operational marine service businesses and jobs, whose goods and services will improve the efficiency of industries presently contributing 200bn ECU per annum to the European GNP.
3. To contribute to the effective management of the environment on a global scale, by predicting the behaviour of the ocean and coastal seas.

The aims of EuroGOOS are to:

- assess the social and economic benefits to Europe from forecasting marine and coastal conditions and the marine contribution to climate prediction;
- prioritise the benefits to Europe from operational oceanography;
- promote the development of technological, computer and science based industries that will advance European operational oceanography for predicting the state of the ocean;
- establish a concerted European approach to the planning and implementation of the GOOS;
- ensure routine collaboration between European national and multi-national agencies so as to obtain maximum economic and social benefit from the new business of operational oceanography.

It is significant that EuroGOOS is not an intergovernmental organisation but an arrangement by which ‘bottom up’ drive can be focused and ‘critical mass’ assembled. In this context, since 1989, the European Commission has supported a Marine Science and Technology (MAST) Programme, whose objective is ‘ to foster the scientific knowledge and technological development necessary to understand how marine systems function at basin scales, in order to prepare for sustainable use of the oceans consistent with the preservation of marine environmental quality and to determine their role in global change’. ***The MAST Programme is highly relevant to the purposes of GOOS therefore and has been an important source of funding for initial EuroGOOS R&D activities.***

EUROMAR is a 15 year initiative that began in 1986 and aims to stimulate market-led marine industrial development in Europe, by running workshops, partnering events and conferences to help transfer knowledge and stimulate collaboration, particularly amongst Small to Medium-size Enterprises (SME). It also advises governments and other sources of funding on the suitability of projects for support within the broader framework of the EUREKA research programme. The initiative has contributed to the development of a wide range of marine technologies, extending from automated sensors, platforms, data management systems and modelling techniques.

A ‘Strategy for EuroGOOS’ (Woods et al., 1996) has been widely distributed and was published, discussed and affirmed at a conference held for this purpose in October 1996. This sets out phases for the progressive achievement of the goals and aims; phase 1 from 1996 to 1998, phase 2 from 1998 to 2002 and phase 3 from 2002 to 2006, and beyond. ***The essence of the strategy is to segment and then analyse the tasks that need to be completed in some 10 interdependent but discrete sectors.*** This ensures that different specialist activities proceed in a vigorous but orderly fashion, recognising the many interdependencies that exist in a venture on this scale. The strategy also recognises that it is not possible to operate on the basis of a wholly prescriptive plan; there are many unknowns that can only be resolved by trials, pilot projects and the incremental steps that are a hallmark of the wider GOOS. Because the oceans and seas know no national boundaries, problems and benefits vary from one region to another and the missions and capacities of agencies are not uniformly distributed, it is also convenient to segment the problem on the basis of the major marine features of Europe.

EuroGOOS

The EuroGOOS Plan (Woods et al., 1997) identifies regional projects, with distinctive structure and objectives, each of which has a Task Team and an agreed programme of work. These projects are supported by a number of working groups, discrete studies and analyses that are generic or cross cutting. Thus, ***Advisory Working Groups are available to assist with scientific and technical issues,*** a project to generate a standard gridded bathymetry for the NW shelf area is proposed and studies to determine user needs have been conducted in several countries. ***A study group has been set up to advise on aid and capacity building.***

The objectives of the regional Task Teams are:

- for the Arctic Ocean
  – to develop an operational monitoring and forecasting system for the Arctic marine region; to detect trends in sea ice parameters to help the prediction of climate change; to monitor sea ice parameters and dynamics as an aid to fishing, shipping and offshore industries; to monitor the spread of algal blooms and contamination;
- for the Baltic Sea
  – by building on existing co-operative efforts amongst the riparian States, to develop and operate new services as EuroGOOS demonstrators, giving priority to monitoring and warning systems for sea ice, currents, sea level, waves and harmful algal blooms;
- for the Mediterranean Sea
  – to develop a nowcast/forecast system for fisheries management, flood prevention and the control of pollution;
- the North West European Shelf project is reviewed in the accompanying boxed section.
- for the Atlantic Ocean
  – by building upon current investments in observing systems, assimilation methods and models on the scale of the Atlantic, to build test and develop a pre-operational eddy resolving ocean modelling system that will be capable of supporting shelf and coastal modelling and services and providing open-ocean products.

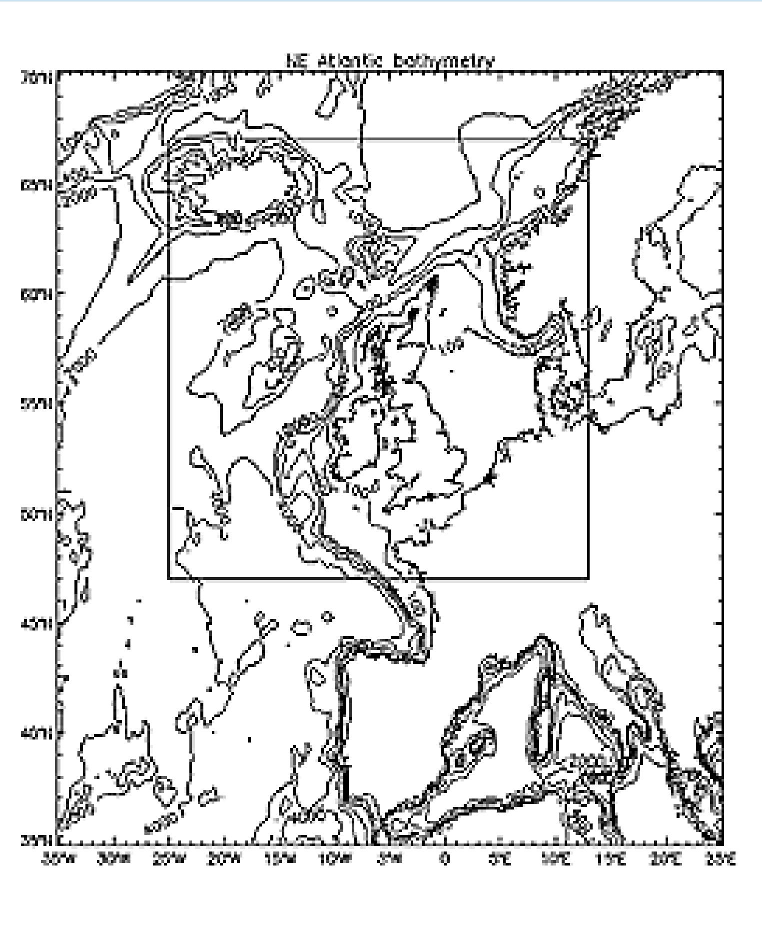
The combination of EuroGOOS, MAST and EUROMAR has contributed to the development of a number of observing systems and sensors, against specifications that have a sound user base and encourage inter-connectivity and compatibility. These have included buoy and platform systems/sensors, profilers, towed vehicles etc. A standard instrumental package for installation on the many ferries that ply European waters is under consideration.

EuroGOOS

The EuroGOOS North-west European Shelf project

To achieve its goals and aims, EuroGOOS has decided to pursue a number of regional projects. One of these is focused on the North West European Shelf Seas, which include all the shallow seas from Norway, round the Shetland Islands, Scotland, Ireland, the south west UK, and to southern Brittany

The region is relatively well observed and studied, often through national programmes, the greater coordination of which may offer some economies of scale. The major customers for services in the region are the off-shore oil and gas industries, the agencies responsible for coastal protection, and the regulatory authorities who seek to balance the multiple uses of this environment. There is extensive leisure use of the region and it is heavily fished. The domain has been modelled extensively for many years, initially for diagnostic purposes but increasingly to predict outcomes in near real-time. Physical, chemical and biological modelling has been carried out successfully. The North West Shelf has a very significant open boundary problem to be tackled and solved.



A Task Team was set up to:

- **identify the bodies carrying out work relevant to the development of operational oceanography there;**
- **examine customer requirements, including major proxy customers;**
- **identify the needed observations and data products;**
- **identify the technology, installations, operational models, and other operational system components;**
- **specify unique or special requirements for the region;**
- **catalogue those models and forecasting systems already under trial or in operation here.**

The Team identified a need for information services based on: Temperature (surface and sub-surface), salinity (surface and subsurface), wind field, barometric pressure, rainfall, evapotranspiration, wave field and spectra, heat flux, currents (tidal, wind driven, residual, shelf edge), sea level, storm surge, shelf edge fluctuations, nutrients (nitrate, nitrite, phosphate, silicate, oxygen), suspended sediments, sediment transport, properties of coastal wetlands, sound velocity in sea water, light transmissivity, chlorophyll, fluorescence, and variation in seabed bathymetry and bedforms.

Existing operational models provide information services relating to: wind and wave characteristics; currents; sea water temperature and salinity; sea level, tides, and storm surges; and aspects of water

quality, water constituents, and sediment transport. Hydrodynamic models in the North Sea region have a spatial resolution of the order of 600m. There is an urgent need to improve modelling capability to include predictions of biogeochemical processes and sediment transport.

To design and specify a new range of observing instrumentation it is necessary to document the range of existing instrument stations that deliver data reports in real time. The 'SeaNet' group has started such an inventory for the fixed stations on the North Sea coast and the Irish coast. EuroGOOS is collaborating with 'SeaNet' to increase the inventory of routine observations in all the NW Shelf seas.

The technology appropriate for a monitoring service in this area includes Compact Airborne Spectral Interferometry (CASI), satellite remote sensing, moored buoys, coastal instruments and tide gauges, ship-borne sections, HF radar, and observations from off-shore oil rigs. There is an urgent need for improved chemical sensors. The installation of standard instrument packages on board commercial Ferries is likely to be an effective method for obtaining water quality and physical oceanographic data.

Improved bathymetric definition of the shelf seas is a priority if model performance is to be enhanced. A 'High Precision Gridded Bathymetry Project' is being pursued. A proposal is being made for EC funding to carry out a NW shelf data assimilation and forecasting experiment, to integrate observing systems and operational models in the generation of services for which a demand has been identified, on the same time scale as the GODAE project (6.7).

Significance and implications for the GOOS

The ingredients that seem to be making a success of EuroGOOS are:

- the active participation of the operational agencies who are likely to provide new or improved services, for which there is a demand;
- involvement of the research communities who are able to advise on the feasibility of incremental improvements in capability and their likely impact;
- a good knowledge of the installed base of relevant observing, modelling and operational information distribution systems;
- a significant but affordable proposition to place before funding agencies, that is likely to deliver political, social and/or economical benefits. In this case the overall goal of EuroGOOS to create new businesses and employment, the possibility of improving the efficiency and effectiveness of industry and commerce, and of achieving greater integration, and economies of scale in the European information service sector, are all germane.

EuroGOOS is also providing another possible model for regional implementation of the GOOS. It differs from that of NEAR-GOOS in several important respects. In particular, as concerns the availability of a common source of funding for regional development and in the role and responsibilities of agencies.

6.5 Managing the problems of the Black Sea

The drainage basin of the Black Sea occupies almost a third of the land area of continental Europe and contains parts of seventeen countries, thirteen capital cities and some 160 million people. But the Black Sea's only connection to the world's oceans is the narrow Bosphorous channel. The Bosphorous is as little as 70 metres deep and 700 metres wide whilst the Black Sea is up to two kilometres deep. The rivers provide abundant nutrients, in particular phosphorus and nitrogen, making the Black Sea very fertile. Phytoplankton form the base of the food chain and are either eaten or die and fall to deeper waters where they are decomposed by bacteria. This action rapidly consumes all available oxygen. Replenishment of bottom waters of the Black Sea from the Mediterranean is slow and does not provide oxygen at a sufficient rate to balance the consumption within the Black Sea itself. As a result the Black Sea is the biggest natural anoxic basin in the world, being essentially devoid of aerobic life below about 180 metres. Despite this, for millennia, its surface waters have supported a rich, diverse marine life, abundant fisheries and, more recently, a substantial tourist industry.

Since 1970, the Black sea has suffered a catastrophic degradation of its natural resources. Increased nutrients washed down by rivers caused an overproduction of certain types of phytoplankton that blocked light from reaching the sea grasses and algae, essential components of the ecosystem of the north-western shelf. As a result the entire ecosystem began to collapse. This problem, coupled with other forms of pollution and irrational exploitation of fish stocks led to a sharp decline in fisheries resources. To make matters worse, in the mid eighties, a jellyfish-like species (Mnemiopsis leidyi), was accidentally introduced into the Black Sea in ballast water. Its diet included fish larvae and zooplankton. It quickly reached a total mass of 900 million tonnes (ten times the annual global fish harvest!). Uncontrolled sewage discharge, the dumping of solid wastes into the sea and accidental/operational releases of oil have all added to the problem. Clearly, the exploitation of the Black Sea's resources during the last few decades has been unsustainable.

The resources of the Black Sea – and its problems – are shared predominantly by the six coastal states, Bulgaria, Georgia, Romania, Russia, Turkey and the Ukraine, although part of the responsibility for controlling aquatic and airborne pollution is shared with the other eleven countries in the region. The first task in solving problems of this kind has to be a wide ranging review of the needs of the major stakeholders, knowledge of the international framework within which actions are to be taken, and the science and technology that is available for devising solutions.

In the last decade, the science base on which to build an understanding of the problems of the Black Sea has benefited from the ***Co-operative Marine Science Program for the Black Sea (CoMSBlack),*** a self-initiated,

non-governmental organization of participating scientists from within and outside the region, that was adopted as a programme of the IOC in 1993. Its objectives are to provide knowledge of the physical and biochemical conditions and processes, and the associated models needed to inform management decisions. Initially, it coordinated general surveys, process studies, and research into coastal seas circulation dynamics and fluxes. It held at least one major multi-ship cruise per year, produced 100 publications, and developed a team of 60 to 100 local scientists who collaborate, inter-calibrate their instruments, use common manuals and procedures, and share data and models. At present, the Program focuses on shelf and nearshore processes.

Managing the problems of the Black Sea

An important step in the establishment of a new framework for action was the establishment, through 1992-94, of a legal framework for co-operation, inspired by the Regional Seas Conventions, entitled the "Convention for the Protection of the Black Sea against Pollution" – the so called "Bucharest Convention". The Convention includes a basic framework of agreement and three specific Protocols on:

- the control of landbased sources of pollution,
- dumping of waste, and
- joint action in the case of accidents (such as oil spills).

A Commission, with a permanent secretariat in Istanbul (the Istanbul Commission), was also created. Goals, priorities and a timetable needed to bring about environmental action were agreed at Ministerial level, based largely on the 'Agenda 21' - section 3.1.6.

A three year ***Black Sea Environmental Programme (BSEP)*** was established in 1993 with the help of funding from the GEF, the EU, The Netherlands, France, Austria, Canada and Japan. Although most Black Sea countries had many experts in science, engineering, economy and law, the linkage between their work and decision-making on environmental matters was poor. Many institutions lacked the equipment and know-how to provide reliable information on the state of the environment. Such information is essential for devising new policies and laws and assessing their effectiveness. Capacity building was an essential early priority therefore – principle 1.3.2 (G).

The realities were addressed at the first meeting of the BSEP Steering Committee in June 1993. Representatives of Black Sea Governments met with the GEF Partners, donors and representatives of NGOs, in order to define a three-year workplan. The meeting selected three objectives

- to improve the capacity of Black Sea countries to assess and manage the environment;
- to support the development and implementation of new environmental policies and laws;
- to facilitate the preparation of sound environmental investments.

The first challenge was to rebuild the institutional linkages needed to effectively assess priorities and to manage the environment.

A network of over 40 institutions is linked by e-mail. A Black Sea Data System and Black Sea GIS ensure the availability of information to scientists, managers and policy-makers. The initial emphasis in the area of data capture and exchange has been on:

- assessment of discharges of chemical and micro-biological contaminants;
- pilot studies to monitor the levels and effects of contaminants for compliance and long term trends;
- maintaining the performance of the data system and expanding the range of users;
- LMR.

BSEP has contributed more than $1.5 million on re-equipping its pollution monitoring network, concentrating on measurements of total suspended sediments, biological oxygen demand, total nitrogen and phosphorous.

An important product of a Programme Co-ordinating Unit set up by the Istanbul Commission was a Transboundary Diagnostic Analysis, published in June 1996. The Analysis has three levels: a listing of the seven major problems of environmental degradation, their causes and action areas; an overview of the actions proposed for each issue; and information on the "action areas" and related issues. The Analysis served as the basis for a ***Strategic Action Plan for the Rehabilitation of the Black Sea*** as called for in the Bucharest Convention. This Plan was adopted by the Environmental Ministers of the Black Sea nations in Istanbul 30-31October, 1996. It specifies Policy Actions in the action areas, directs each nation to prepare national Strategic Action Plans, and charges the Istanbul Commission with its implementation. The Programme Co-ordination Unit will take over and manage the infrastructure developed by BSEP, including maintaining the electronic communication system and GIS and acting as a data clearing house, and will establish Advisory Groups based on the BSEP Working Parties.

The Action Plan emphasises reduction of contaminant influxes, particularly from the Danube, from several land based point-sources and from vessels, through enforcement. A monitoring system, based upon measurements of biological effects and key contaminants, is to be established. It is to have an independent quality assurance system. Other measurements focus on bathing water quality, discharges from point sources and through rivers, and critical LMR stocks.

Because Black Sea remediation requires reduction of the river-borne transport of damaging substances, GEF has established parallel programs for the Danube Basin and the Danube Delta, ***– the Environmental Program for the Danube River Basin.***

No attempt has yet been made to introduce a comprehensive modelling capability, but a ***NATO TU-Black Sea Project,*** subtitled ***Modelling As A Management Tool For The Black Sea: A Regional Program Of Multi-institutional Cooperation,*** was created to develop interdisciplinary community models for the dynamics of the lower trophic levels of the biological community as affected by anthropogenic changes and physical processes. This project has been followed by another NATO project ***– The Black Sea Ecosystem Process, Prediction and Operational Data Management Project.***

6.5
PROTOTYPE OBSERVING PROGRAMMES

Managing the problems of the Black Sea

The IOC Black Sea Regional Committee in September, 1996, agreed to set up the initial phases of two projects. The first, named the ***Black Sea Marine Services (BLACKMARS)*** project, aims to restore, or implement, a basic, operational, monitoring network, including data exchange, processing and predictive tools. The necessary co-ordination amongst the riparian States can best be accomplished through the framework of GOOS. The second is targeted upon the time-space variability of sediment flux in the Black Sea.

To assist in more effective management of the Black Sea a Science Plan for a ***Black Sea Observation and Forecasting System (BSOFS)*** (Vest and Unluata, 1997) suggests exploring, quantifying and predicting the ecosystem variability of the Black Sea from the basin to the shelf scale over time scales extending from days to months. The plan has four core projects, to be tackled over a 10 year period:

- the development of coupled physical-biological-chemical-ecosystem dynamical models;
- the design and development of a comprehensive observational network, based on existing regional capabilities and global observing systems – in particular satellite systems.
- the design and conduct of process studies directed, in particular, to the dynamics of the lower trophic levels of the marine ecosystem;
- to develop an effective data base management system.

Significance and implications for the GOOS

It is clear from the experience in the Black Sea that ***the first and foremost requirement for effective management of the environment is a sound scientific, and hence numerate, understanding of the environment in question, of the key processes that are taking place and of cause and effect.*** The findings of the early surveys that it was the flux of nutrients rather than of metals that was the cause of the most severe problems is an example of this.

In general, where the environment is marine, understanding is likely to be multi-disciplinary in nature and has to be shared and accepted by the riparian states. ***The existence of an institutional and legal framework within which action can be taken is also a sine qua non.*** The glue that holds such frameworks together is shared, credible information – with much of that credibility coming from the science. Not surprisingly, therefore, the early priorities for improved management of the problems of the Black Sea were the collection and sharing of basic data about the environment. The exchange and interpretation of these data has created a significant, distributed body of influential individuals able to attract funding, bring about necessary political and legal changes and, through capacity building, create effective standing organisations. Such organisations have to be mandated, and able, to take operational action and continue to access environmental information that is necessary to monitor the effectiveness or otherwise of those actions.

The lessons for the GOOS are:

a. ***data have to be transformed*** through the application of good science ***into information and advice usable by management.***

b. ***a framework for action has to be in place;*** otherwise, the value of the resulting information cannot be realised. The case for the GOOS, as an operational, long-lived activity is weakened if such frameworks are not in place.

c. 'Bricks cannot be made without straw' and ***capacity to collect and process data, and to take management action, has to be built.*** For the Black Sea environment, ***partnerships between local and international agencies, encouraged by the NATO Partnerships for Peace programme, and the availability of GEF funding have been crucial in this regard.***

6.6 The Benguela Current Large Marine Ecosystem (BCLME) study

The BCLME, situated off the west coast of southern Africa is one of the world's four eastern-boundary upwelling systems. It's high level of primary production supports an important global reservoir of biodiversity and biomass of fish, seabirds and marine mammals (O'Toole and Shannon, 1997).

The BCLME is subject to considerable environmental variability. The extent and intensity of coastal upwelling throughout the Benguela is determined primarily by the wind/pressure field, but the region is also influenced by a number of oceanic processes operating on various temporal and spatial scales. The extreme events are thought to be caused by sustained intrusions of anomalously warm, nutrient poor tropical water across the northern, western and southern boundaries of the ecosystem, large scale changes in the wind-field and changes in the composition and advection of subsurface waters, in particular in the concentration of dissolved oxygen. Some of the changes are the South Atlantic equivalent of the Pacific El Niño (Shannon et al.,1996). These are not necessarily in phase with the ENSO, although some links with the latter are evident. Others may be a consequence of eddies shed by the Agulhas current. Unfortunately the past monitoring of the Benguela has been fragmented and non-continuous, making the interpretation of records and the establishment of cause and effect difficult.

The environmental variability is manifest in regime shifts, species flips and fluctuations in the distribution and abundance of its marine resources. During recent years, environmental perturbations have had severe impacts on the ecosystem leading to a marked decline in the abundance of pelagic and demersal fish. Increased fishing pressure together with widespread occurrence of toxic algal blooms and high pollution risk associated with ongoing seabed mining have also been of concern.

These events have led to an effort by the three countries of the region (Angola, Namibia and South Africa, members of the Southern African Development Community (SADC)) to coordinate their achievement of sustainable ecosystem management. Two programmes are planned.

The first of these, the Benguela Environment Fisheries Interaction and Training (BENEFIT) programme is a regional fisheries and environment initiative due to commence in 1998. Its primary goal is to develop a fisheries management capacity for the commercially important Sardine, Hake and Horse Mackerel stocks within Namibian and Angolan waters based on both stock assessment and environmental research. The emphasis is on training, the creation of an effective fisheries and an associated environmental monitoring capability in the region. Support is being sought from German agencies for the environmental research projects and from Norway for the fisheries research component.

The second proposal is to launch a World Bank (GEF) funded BCLME study, of 10 years or more, where the primary objective is to build upon work started under the BENEFIT programme and prepare a Strategic Action Plan for the Benguela. This is expected to include:

- the development of mechanisms for consultation and cooperation at regional and national level;
- the development of institutional capacities to enable sustainable management of the BCLME.
- the establishment of effective ecosystem monitoring systems;
- research to increase understanding of the BCLME;
- the harmonisation of policies and legislation relating to activities affecting the BCLME;
- specific measures to implement sustainable development, protect biodiversity and cope with the consequences of natural and anthropogenic climate change.

6.6
PROTOTYPE OBSERVING PROGRAMMES

The Beguela Current Large Marine Ecosystem (BCLME) study

The geographic boundaries of this programme are far more extensive than the BENEFIT programme, that is confined to the shelf system. The BCLME study will consider processes occurring in the wider South Atlantic region that might affect the Benguela system, such as climatically induced changes in oceanic circulation patterns. The GEF has set aside funding to develop this Strategic Action Plan between the three regional governments, for initiation early in 1998. Following that, the plan is to develop an environmental monitoring strategy to be adopted and running as early as 1999.

Significance and implications for the GOOS

This example sustains the point made in paragraph 1.2.3, that there can be prima facie evidence of environmental impacts on and sensitivity to important socio-economic activities, but ***without adequate, reliable information and scientific understanding it is not possible to take effective action to optimise those activities and achieve sustainable development.*** It also echoes the point made in section 6.5, that ***without the necessary policy, legal and institutional infrastructure capable of taking action, information is of little value.***

Therefore, in developing countries, where such fundamental capabilities can be missing, their development must go hand-in-hand with research and sustained, systematic monitoring. The example also demonstrates the importance of coherent monitoring of physical, chemical and biological properties and for the design of temporal and spatial sampling to be guided by an appreciation of the specific characteristics of the domain and the management problem being addressed.

The study and eventual implementation of a long-term monitoring programme will undoubtedly benefit from the fundamental research that has been carried out over the past decade – e.g. Payne et al., 1987 and Payne et al., 1992 – and from the new generation of ocean colour satellite instruments capable of assessing biological productivity; the Benguela region was the site of an important ground truth experiment for the Coastal Zone Colour Scanner (CZCS) of Nimbus 7 (Shannon, 1985). Again this emphasises the importance of such activities as foundations for the GOOS.

6.7 The Global Ocean Data Assimilation Experiment (GODAE)

During 1997 the OOPC formed the view that the long-term sustainability of a truly global ocean observing system for climate depended on a clear demonstration of the feasibility and value of such a system. Accordingly it developed the concept of a Global Ocean Data Assimilation Experiment whose purpose is to create:

a practical demonstration of real-time global ocean data assimilation in order to provide a regular, complete depiction of the ocean circulation at time scales of a few days, space scales of several tens of kilometres, and consistent with a suite of space and direct measurements and appropriate dynamical and physical constraints.

Such a demonstration would deliver a number of capabilities for the period of the experiment – and beyond to the extent that they were retained. They include:

- provision of suitable oceanic boundary conditions for regional applications such as coastal sea prediction systems;
- provision of high resolution upper ocean forecasts and nowcasts;
- a description of the ocean circulation and physics upon which more specialised systems, such as biological models, could be developed and tested;
- a foundation for hypothesis testing, process studies and further experimentation, much as is commonplace in numerical weather prediction;
- initial conditions for climate predictions and analyses for validation of climate simulations; and
- a method for systematic handling, quality control and scientifically consistent interpretation (analysis) of additional data sets such as those from process studies and arising from incidental exploration.

It was also conceived that, leading up to the demonstration, GODAE would act as a unifying target for various research enterprises (observational, theoretical and modelling).

In effect, the proposal is to demonstrate the generic design described in Chapter 4 on a global scale and in real-time. As noted in section 5.2 in connection with TOGA and operational ENSO prediction, the transition of research systems into operational mode demands demonstrations of utility and value, so GODAE can also be seen as a necessary 'lifting by the bootstraps' of this particular manifestation of the GOOS.

The proposal is borne of the conviction that the necessary foundations are in place, as described in chapter 3, or given the will, can be so by the early years of the next century and that the need justifies the effort required.

Specifically the opportunity arises because of:

- the development and maturity of remote and direct observing systems, making global real-time observation feasible;
- the steady advances in scientific knowledge and ability to model the global ocean and assimilate data at fine space and time scales;
- the expectation that the necessary computing power will be in place on a 3-5 year time scale;
- the genuine enthusiasm of the community and, in particular, the remote sensing community, to promote and implement integrated global observing systems; and
- the critical advances provided by research programmes like TOGA and WOCE.

The ***need*** exists, in part, because of the synergy that has to exist between the satellite operators and users of the data they produce. The operators need a demonstration that worthwhile use will be found for the data from the wide range of instruments capable of measuring the fundamental properties of the ocean, that they are committed to launch over the next few years – or evidence that some other suite would be more useful in future. If the challenge of demonstrating one or other of those outcomes is declined, it is likely to be many years before another opportunity arises.

More fundamentally, the global scope of the experiment arises from the need to improve the services to end users by:

- extending the predictability of :
  - regional and local forecasts of operating conditions on the shelf, and
  - seasonal-to-interannual prediction sensitive to oceanic evolution;
- providing genuinely global high resolution upper ocean nowcasts and forecasts to aid transport and naval operations on the high seas; and
- sustaining climate research.

It is the nowcast and short-period forecast requirement and need to obtain the maximum benefit from the real-time flow of data through their assimilation into continuously updated models, that impose the near real-time constraint on the experiment.

Assumptions

Much remains to be done in terms of agreeing the scope and essential features of the experiment. However it is reasonable to assume that it will:

a. include global models of at least eddy-permitting resolution.

b. build to near-real-time operation by the start of the year 2003 and continue with a near-complete global observing system for around 3 years;

The Global Ocean Data Assimilation Experiment (GODAE)

c. encompass a variety of space-borne systems (see 3.6.1) including

- altimetry;
- scatterometers;
- operational meteorological satellites;
- sea surface temperature;
- ocean colour;
- advanced telemetry and communications.

d. include a global *in situ* ocean observing network that, when combined with models and satellite data, provides calibration and information on vertical structure not deducible by other means; for example comprising

- subsurface moorings
- merchant vessels
- autonomous profiling floats
- acoustic thermometry

The remote and direct observing contributions will be complementary. The space program, that is reasonably firm for the target period, provides many of the critical parameters, such as SST, surface wind stress and surface elevation at, or close to, the required spatial and temporal sampling rate.

It is assumed that the experiment will include at least two model and data assimilation systems capable of resolving eddies and ingesting the variety of data types provided by remote sensing and direct sampling of the ocean. The emphasis will be on modelling and assimilation of the ocean above the permanent thermocline in real time; below that level it is expected that the WOCE datasets will provide the necessary definitions of state and dynamics.

The appropriate models and data assimilation methods are likely to be available as a result of the WOCE-AIMS. The US WOCE modelling and data assimilation community have proposed prototypes of the systems envisaged for this experiment. The UK FOAM is an operational ocean circulation model, albeit at coarse resolution. U.S. Navy experience is described in section 3.6.12. The French MERCATOR Project has several aims in common with those of this proposed experiment and could also provide a prototype system for a practical demonstration. Several other national and/or regional efforts, including emerging operational ENSO forecast systems and the IRI are expected to provide valuable input and guidance. Useful experience will be gained in EuroGOOS pilot projects, particularly on the North West European Shelf and in the North Atlantic and from similar developments in the North Pacific.

There will be a strong dependence on surface flux products from operational numerical weather prediction systems.

Significance and implications for the GOOS

GODAE is a proof-of-concept demonstration that collection and assimilation of real time oceanic data into global models is feasible and will deliver valuable capabilities, products and services. As such GODAE is central to the GOOS. It is also a unifying framework for smaller scale experiments and pilot projects that will be carried out en route to that goal. It has been compared in scale with the First GARP Global Experiment (FGGE), that provided a similar proof-of-concept demonstration for global atmospheric observation and modelling in 1978/79. Interestingly this followed a process experiment, the GARP Tropical Experiment (GATE) conducted in 1974, when the objective was to assess the structure, evolution and role of convective cloud systems in the tropical eastern Atlantic.

GODAE is true to the Strategic Plan of the GOOS in allowing, and encouraging incremental implementation. It is unique in that its focus is unequivocally upon the ocean – unlike many of the other components described in chapter 3, that are concerned predominantly with coastal phenomena and atmosphere-ocean exchanges.

GODAE is also of fundamental importance because it has the endorsement and support of major resource holders – in the form of the members of CEOS, academia, and agencies – as well as the JSTC of GCOS and I-GOOS.

The implementation of GODAE was discussed in chapter 5.

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A1.1 Food and Agriculture Organization of the United Nations (FAO)

Since its inception in 1945, the FAO's mission has been to alleviate poverty and hunger by promoting agricultural development, improved nutrition and the pursuit of food security – the access of all people at all times to the food they need for an active and healthy life. The Organization offers direct development assistance, collects, analyses and disseminates information, provides policy and planning advice to governments and acts as an international forum for debate on food and agriculture issues. The FAO is active in land and water development, plant and animal production, forestry, fisheries, economic and social policy, investment, nutrition, food standards and commodities and trade. It also plays a major role in dealing with food and agricultural emergencies.

A1.2 Global Environmental Facility (GEF)

The GEF is a joint programme of the World Bank, UNEP and UNDP, directed by the latter. It was created in 1991 as a 3-year experimental pilot fund operating for environmental issues. It was accepted at the UNCED as the main interim funding mechanism for the implementation of Agenda 21 and the Conventions on Climate Change (FCCC) and Biodiversity. It was restructured in 1994 and replenished with a $2 billion commitment from 26 countries.

A1.3 Intergovernmental Oceanographic Commission (IOC)

The IOC is a body with functional autonomy within the United Nations Educational, Scientific and Cultural Organization, whose purpose is to promote marine scientific investigations and related ocean services, with a view to learning more about the nature and resources of the oceans through the concerted actions of its members. The Commission is enjoined to pursue its objectives through collaboration with other relevant organizations within and outside the UN system. Programmes sponsored and coordinated by the Commission and recommended to member States, are carried out with the aid of the resources of participating States according to the obligations they are willing to assume.

A1.4 International Council for the Exploration of the Sea (ICES)

Since its establishment in 1902, ICES has been a leading scientific forum for the exchange of information and ideas on the sea and its living resources, and for the promotion and coordination of marine research by scientists within its 18 member countries on both sides of the North Atlantic. The Council is concerned with the broad areas of fisheries, oceanography and the marine environment. It aims to meet the needs of its member countries and the regulatory commissions concerned with the efficient use marine fish and shell fish resources in the North Atlantic, including the North and Baltic Seas, and with the protection of the marine environment from the harmful effects of pollution. It has published an extensive scientific literature.

A1.5 International Council of Scientific Unions (ICSU)

ICSU is a non governmental Scientific Union which was created in 1931 to encourage and promote international scientific activity in the different branches of science and their applications to the benefit of humanity. Members comprise international scientific unions and national scientific academies or institutions. ICSU fulfils its responsibilities in a number of ways including the initiation, design and coordination of major international, interdisciplinary research programmes, and via the creation of interdisciplinary bodies that undertake activities or programmes of interest to several member bodies e.g. SCOR. ICSU also addresses matters of common concern to all scientists, such as science teaching, often in co-operation with other bodies.

A1.6 International Maritime Organization (IMO)

The purposes of the International Maritime Organization, as summarized by Article 1(a) of the Convention, are "to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships". The Organization is also empowered to deal with administrative and legal matters related to these purposes. The Organization has 155 Member States and two Associate Members.

A1.7 Scientific Committee on Oceanic Research (SCOR)

SCOR was established in 1957 by ICSU to further international activity in all branches of oceanic research. Forty countries are currently members of the Committee. It carries out its mandate by examining specific problems through its scientific working groups and through longer-term steering committees for global programs. SCOR is the lead organization responsible for the development and implementation of JGOFS and the program on GLOBEC, both of which are also Core Projects of the IGBP. Other activities extend to methodological issues, the development of standards, enhancement of international action, science policy and national and international cooperation with WMO, WCRP and other bodies concerned with oceanography.

A1.8 World Meteorological Organization (WMO)

The purposes of WMO are to facilitate international cooperation in the establishment of networks of stations for making meteorological, hydrological and other observations; and to promote the rapid exchange of meteorological information, the standardisation of meteorological observations and the uniform publication of observations and statistics. It also furthers the application of meteorology to aviation, shipping, water problems, agriculture and other human activities, promotes operational hydrology and encourages research and training in meteorology.

A1.9 United Nations Development Programme (UNDP)

The UNDP is the world's largest multilateral source of grant funding for development cooperation. Funds come from the voluntary contributions of Member States of the United Nations and its affiliated agencies, which provide approximately US$1 billion yearly. A 36-member Executive Board composed of both developed and developing countries approves major programmes and policy decisions.

UNDP has declared three goals:

- to help the United Nations become a powerful and cohesive force for sustainable human development;
- to focus its own resources on a series of objectives central to sustainable human development: poverty elimination, environmental regeneration, job creation, and advancement of women;
- to strengthen international cooperation for sustainable human development and serve as a major substantive resource on how to achieve it.

A1.10 United Nations Environmental Programme (UNEP)

UNEP provides a mechanism through which a large number of separate efforts by intergovernmental, non-governmental, national and regional bodies in the service of the environment are reinforced and interrelated. The programme recognises that the environment cannot be compartmentalised and is a system of interacting relationships that extends through all sectors of activity. It is also predicated on the conclusion that environment and development must be mutually supportive, as set out in the Agenda 21 action programme. UNEP makes a particular effort to nurture partnerships with other UN bodies possessing complementary skills and delivery capabilities as well as increasing the involvement of the private sector, the scientific community, and other NGOs in the achievement or sustainable development. UNEP's work programme for the biennium 1996-97 emphasises relationships between socio-economic driving forces, environmental changes and impacts on human well-being. The Regional Seas Programmes, the GPA/LBA, the initial Global Environmental Outlook assessment published in 1997, and its partnership in the GEF have particular significance for the planning and implementation of the GOOS.

A brief history of the GOOS

The impetus for the creation of a GOOS came from the IOC Committee for Ocean Processes and Climate (OPC) in the late 1980s. In March 1988, the 21st Executive Council of IOC created an expert group to prepare proposals for the development of a GOOS, and was supported in this by the WMO Executive Council in June 1989, and by the 15th IOC Assembly in July 1989. First 'official' use of the phrase GOOS came in the 23rd IOC Executive Council in March 1990. Later that year the Second World Climate Conference called for a GOOS to be a major component of the proposed GCOS. In March 1991, on the recommendation of the OPC, the 16th IOC Assembly decided to undertake development of a Global Ocean Observing System (GOOS) and to establish a GOOS Support Office (GSO). In May 1991, WMO's 11th Congress accepted the invitation of IOC to cosponsor the GOOS. Thus the GOOS could be said to have come into being in 1991.

The GOOS was intended as a logical progression following from the WOCE, the implementation of which had commenced in 1990. Its creation also reflected the desire of many nations to establish systems of ocean observations dealing with environmental, biological and pollution aspects of the ocean and coastal seas, to raise the capacity of less well developed nations to acquire and use ocean data effectively and to integrate existing systems of observation and data management within a coherent framework.

In response to advice from the OPC, the 25th IOC Executive Council in March 1992 authorised formation of (i) an Intergovernmental committee for GOOS (I-GOOS), which was eventually jointly sponsored by IOC, WMO and UNEP to provide intergovernmental coordination in the implementation of GOOS, and to replace the OPC, and (ii) a GOOS Technical and Scientific Advisory Panel, that subsequently became known as J-GOOS and was jointly sponsored by IOC, WMO, and ICSU. The first I-GOOS Committee meeting took place in February 1993, and the first J-GOOS meeting in May 1994.

An 'executive' Strategy Sub-committee (SSC) of I-GOOS was created in 1994, which commenced the development of a GOOS Strategic Plan in 1995. In 1997 it was decided to merge the functions of the SSC and J-GOOS into a jointly sponsored GOOS Steering Committee (GSC). The GSC, responsible for all expert aspects of GOOS planning and implementation will come into being at its first meeting in April 1998, under the chairmanship of Professor Worth Nowlin. Dr Angus McEwan is the current chairman of I-GOOS.

The planning of the 'Climate Module' of GOOS predates GOOS itself, having been the task of an Ocean Observing System Development Panel (OOSDP) set up by the IOC/WMO/SCOR Committee for Climatic Changes and the Ocean in 1989. The OOSDP is now succeeded by an ongoing Ocean Observations Panel for Climate (OOPC) jointly sponsored by GOOS, GCOS and the WCRP. The HOTO Panel was established as an ad hoc group in 1993, and became a formal advisory group to J-GOOS in 1994. An ad hoc LMR Panel met in 1993 and again in 1996, and an ad hoc Coastal Panel met in 1997; both were was established as formal panels reporting to the GSC, in 1998. A number of meetings of these and other expert panels has been held.

To implement the actions of the above planning bodies, the GOOS Project Office (GPO) (originally the GSO) was set up within the IOC Secretariat in 1992. A GOOS Director, Dr Colin Summerhayes, was appointed by UNESCO in 1997.

Annex 2

Memorandum of Understanding on the co-sponsorship of the GOOS Steering Committee and Terms of Reference of the GOOS Modules and G3OS Panels/Workshops

MEMORANDUM OF UNDERSTANDING BETWEEN THE INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION, THE WORLD METEOROLOGICAL ORGANIZATION, THE UNITED NATIONS ENVIRONMENT PROGRAMME AND THE INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS ON THE CO-SPONSORSHIP OF THE GOOS STEERING COMMITTEE

The Intergovernmental Oceanographic Commission (IOC), the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Council of Scientific Unions (ICSU):

Recognizing the initiative of the IOC to create an operational Global Ocean Observing System (GOOS) for the purpose of collecting comprehensive information on the properties and variability of the Earth's ocean system; for assisting in the detection of climate change and assessing its impact; to provide a basis for the development of national and international policies for resource management, coastal development and management; for assessing and preserving the health of the ocean; and for promoting related capacity building and ocean science and its application,

Considering that the required information and interpretation will involve data from activities designed specifically for GOOS, as well as from existing operational oceanographic and meteorological programmes, and data, observations and understanding from a variety of research programmes, and that the GOOS will collaborate with the Global Climate Observing System (GCOS) in the definition and the implementation of the ocean-related component of the GCOS, as provided for in the Memorandum of Understanding which set up the GCOS, signed by WMO, IOC, ICSU and UNEP,

Considering further that an operational GOOS will provide data and information essential for the implementation of Chapter 18 of Agenda 21, adopted by the United Nations Conference on Environment and Development (UNCED), for the Framework Convention on Climate Change (FCCC), and for the Global Plan of Action for the Protection of the Marine Environment from Land-Based Sources of Pollution (the GPA),

Recalling that the mandate of ICSU is to foster international co-operation in scientific research and the application of scientific knowledge to improving our understanding and stewardship of the global environment, and that the special responsibilities of IOC, WMO and UNEP include encouraging the co-operative action of governments in all matters dealing with the ocean and atmosphere,

Agree to co-operate in the scientifically based design, planning and implementation phases of the Global Ocean Observing System for the following reasons:

(i) the planning effort requires the full involvement of the scientific community as represented by both intergovernmental and non-governmental organizations, such as the IOC, WMO, UNEP and ICSU,

(ii) the design and testing process will result in broadly applicable scientific and technical advances,

(iii) the prospect that when GOOS becomes operational it will provide data that will also advance our scientific understanding of the ocean and enhance the data sets being acquired by on-going and planned research programmes such as those of IOC, IGBP, WCRP and SCOR,

(iv) the ocean data set to be provided by GOOS is a valuable component of that required for the GCOS,

(v) there will be important benefits from GOOS for a wide range of marine activities including fisheries, coastal seas management, shipping, off-shore mining and waste disposal.

Agree, therefore, that the proposal to establish a GOOS Technical and Scientific Advisory Panel (Resolution IOC XXV.3) shall be implemented jointly by IOC, WMO, UNEP and ICSU by establishing a GOOS Steering Committee, to supersede the previous Joint GOOS Scientific and Technical Committee, which shall operate in accordance with the following principles:

(i) The IOC/WMO/UNEP Intergovernmental Committee for GOOS (I-GOOS) is the recognized intergovernmental forum for nations participating in GOOS, including for the commitment of resources for GOOS implementation and related oversight.

(ii) The GOOS Steering Committee will be recognized as the primary international body responsible for:

(a) The scientifically based design and testing of GOOS;
(b) Coordination of the GOOS planning and implementation process;

(iii) The initial sponsors of the GOOS Steering Committee should be IOC, WMO, UNEP and ICSU. The Scientific Committee on Oceanic Research of ICSU, being the principal ICSU body responsible for matters relating to ocean research, and, at the same time, the principal Scientific Advisory Body to the IOC, shall be involved in the scientifically based design and planning for GOOS.

(iv) The Executive Heads of IOC, WMO, UNEP and ICSU after consultation with the appropriate Members of their organizations and in accordance with the procedures outlined in the Annex to this Memorandum, shall jointly:

a) Appoint the Chairman and members of the GOOS Steering Committee,
(b) Arrange for the expansion of the GOOS Secretariat, located within the IOC Secretariat, to increase the GOOS Steering Committee secretariat staff,
(c) Arrange for the necessary financial support for the GOOS Steering Committee and its secretariat staff in accordance with the provisions of Section 7 of the Annex to this Memorandum,
(d) Harmonise and coordinate GOOS activities, both internally and with the other global observing systems.

Annex 2

TERMS OF REFERENCE OF THE OCEAN OBSERVATIONS PANEL FOR CLIMATE

Recognizing the need for scientific and technical advice and guidance for the common module of the Global Climate Observing System and the Global Ocean Observing System, and the need for liaison and co-ordination between operational observing systems and those of climate research programmes, the GCOS-JSTC, J-GOOS[6] and the JSC for the WCRP have established an Ocean Observations Panel for Climate with the following terms of reference:

(i) To evaluate, modify and update, as necessary, the design of the observing system for the common module of GOOS and GCOS whose goals are:

- to monitor, describe and understand the physical and biogeochemical processes that determine ocean circulation and the effects of the ocean on seasonal to multi-decadal climate change,
- to provide the information needed for climate prediction.

(ii) To provide a procedural plan and prioritisation for an integrated set of requirements consistent with the observing system design criteria, thereby also drawing from findings of WOCE and TOGA, and in a form that enables timely and effective implementation.

(iii) To liaise and provide advice, assessment and feedback to other panels in task groups of GCOS, GOOS and WCRP, as requested, concerning ocean observing for climate in order to ensure that the designs and implementation schedules are consistent and mutually supportive.

(iv) To establish the necessary links with scientific and technical groups to ensure that they are cognizant of, and can take advantage of the recommended system, and that, in turn, the Panel can benefit from research and technical advances.

(v) To carry out agreed assignments from and to report regularly to the JSTC, J-GOOS and the JSC for the WCRP.

[6] *now the GOOS Steering Committee*

TERMS OF REFERENCEOF THE HEALTH OF THE OCEAN (HOTO) PANEL

The HOTO Panel[7] will be responsible for:

1. Ensuring continued updating of the Strategic Plan for HOTO to adequately reflect scientific understanding and technical capability arising from relevant research and development by:
   - maintaining liaison with research and monitoring activities to ensure that assessments and predictions of the health of the oceans are based on sound and contemporary scientific knowledge; and
   - developing interactions with other scientific and technical bodies and programs relevant to the development of GOOS (i.e., ICES, PICES, EuroGOOS, LOICZ, etc.);
   - In consultation with Coastal and LMR Panels, to develop the HOTO Implementation Plan.
2. Analysing further environmental health criteria or indices that can provide early warning of change in marine environmental quality and threats to human health;
3. Co-ordinating with other GOOS Modules to ensure compatible strategic and scientific development of all GOOS Modules;
4. Identifying the requirements, nature and availability of models that can facilitate the proper development of HOTO products and/or allow prognostic prediction of potential/future conditions relating to the health of the oceans;
5. Identifying the scientific components of training, mutual assistance and capacity building, to undertake regional assessments;
6. Examining the content of existing operational systems, both national and international, that deal with the health of the oceans with a view to advancing GOOS; and
7. Defining HOTO products and socio-economic benefits relevant to the requirements of specific users and describing the procedures leading from the base variable measurements, through scientifically valid interpretation, to the preparation of such products and benefits.

[7] *These terms of reference are as revised at the fourth meeting of the HOTO panel, 13-17 October 1997, and are subject to approval by the GSC.*

TERMS OF REFERENCE OF THE GOOS COASTAL COORDINATING/OVER-SIGHT MODULE PANEL

1. The panel is initially appointed for two years, and shall report to each meeting of the GOOS Steering Committee (GSC). Every session of the GSC 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 GOOS Coastal Module Workshop held in February 1997, combined with recommendations from existing members of J-GOOS, and inquiries 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 chairman of J-GOOS (subsequently the GSC).

4. Meetings, publications, and other activities incurring costs, shall be planned in consultation with J-GOOS (or its successor the GSC) 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 (or its successor body), but only for a period of one year on each occasion, or until the next meeting of J-GOOS (or the GSC), whichever is the longer.

OBJECTIVES

1. To review progress, advise and report upon those activities of the GOOS component bodies, the GOOS Project Office, and participating member states and agencies which relate 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 To provide guidance and advice to J-GOOS (and its successor) on matters concerning the coastal zone.

4. To communicate with other GOOS module panels, to ensure that the activitiesof the GOOS coastal panel are carried out in such a way as to maximise the effectiveness of the GOOS as a whole, taking into account the requirements specified by other panels or components of the GOOS.

5. To communicate with other agencies, committees and programs on behalf of J-GOOS (and its successor), 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.

7. To develop the coastal module implementation plan.

TERMS OF REFERENCE OF THE GOOS LIVING MARINE RESOURCES PANEL

The LMR Panel will be responsible for:

1. The strategic development and detailed scientific and technical design of the observing system for the Living Marine Resources module, consistent with the overall principles of the GOOS.

2. Maintaining liaison with research (particularly GLOBEC and LOICZ programmes) and monitoring activities (e.g. OSLR and FAO) to ensure that the monitoring and predictions carried out by LMR/GOOS are based on sound and contemporary scientific knowledge.

3. Co-ordination with other modules of the GOOS (in particular the COASTAL and HOTO modules) for the purpose of ensuring compatible strategic and scientific development of all components of the GOOS.

4. Design and development of the analysis and modelling ‘products’ derived from the LMR observing system to address the needs of various user groups,

In particular, the LMR Panel should take the following actions as soon as possible:

1. Identify the present and potential users of the data and products of a GOOS-LMR programme and ensure that the design and implementation of GOOS-LMR responds to their needs.

2. Take into account the observation requirements of the other modules of the GOOS in defining the LMR variables and observations needed, and stimulate numerical modelling and other studies to support the objectives of the LMR module with special attention to accuracy, calibration of observing procedures, quality control and spatial and temporal resolution of sampling.

3. Assess the availability of relevant existing data and observing systems, and the capabilities and activities of developing coastal states, and ensure that these consider ations are incorporated into the GOOS LMR design.

4. Develop a plan for the design and implementation of an observing system which would provide the data required by LMR consistent with data provided for the general underpinning of the GOOS and the data required by other modules. That is the LMR should build upon planned datasets and data fields being provided by the global and coastal implementation themes. Variables and parameters should be selected with reference to their importance for detection of changes in the structure, behaviour, and biodiversity of marine ecosystems including the status of fishery resources.

5. Actively coordinate LMR planning with other GOOS module efforts by attendance at relevant HOTO, Coastal and OOPC-sponsored meetings.

6. Produce a detailed outline of the Science Plan for presentation to GSC-1 and an Implementation Plan by late 1998.

TERMS OF REFERENCE OF THE JOINT DATA AND INFORMATION PANEL

Recognizing the need for a comprehensive approach to formulate, implement, and oversee data and information management of the global observing systems, the JSTC of GCOS, the GOOS Steering Committee (GSC), and the GTOS Steering Committee (SC) have established a Joint Data and Information Management Panel (JDIMP).

The data and information management system for the global observing systems, G3OS, should be developed, to the degree possible, to accommodate data and products from the various components of the global observing systems. To do so, the JDIMP should consist of a core group of members representing the various global observing communities, as well as representatives from contributing disciplines, programmes, and agencies. The JDIMP should possess a broad range of expertise including research scientists, who use and understand global data sets, and data and information management experts responsible for significant components of existing operational and research global information management systems. The JDIMP should be a highly focused "problem solving" group, concentrating on resolving crucial issues affecting the quality and maintenance of global observing system data sets, and access to them. Particular agenda items may require additional experts be invited.

Terms of Reference:

- In concert with the G30S science requirements and associated user communities, formulate and develop the G30S Data and Information Management Plan(s);
- Monitor the overall implementation of the data-related elements of the plans
- Make reports and present recommendations, as required, to the JSTC, GOOS, and GTOS SC on information management issues.

The JDIMP has the following specific responsibilities:

- Based on requirements from the science panels and user communities, to solicit data sets relevant in meeting the G30S objectives;
- To identify gaps in available G30S data sets and coordinate efforts to redress data deficiencies;
- To consider and develop a process whereby data sets may be identified and included as "G30S Data Sets". The process should include an assessment addressing, inter alia:
  - that the data quality meets standards acceptable to peers of the submitting scientists using that type data, or to standards appropriate for specific applications,
  - that the data contain documentation (metadata) of a standard allowing adequate appreciation of the data quality,
- To identify the cross-cutting data and information management themes and establish a practical framework (e.g., metadata guidelines, information centre requirements, etc.) for these activities within the observing systems;
- To review, advise on, and provide oversight of the G30S information management system(s) to ensure for example:
  - that access to data and products is provided as required,
  - that archiving activities are adequate.

TERMS OF REFERENCE OF THE GLOBAL OBSERVING SYSTEMS SPACE PANEL

Recognizing the need for a comprehensive approach to the various space-based observational activities for the global observing systems, the JSTC of GCOS, the Joint Scientific and Technical Committee for the GOOS (J-GOOS)[8], and the Steering Committee (SC) for the GTOS have established a Global Observing Systems Space Panel (GOSSP).

Terms of Reference:

Based on guidance from the JSTC, J-GOOS, and the SC, the primary tasks of the Panel are:

- To maintain and further develop the plan for the space-based observation components of the global observing systems considering the requirements from the scientific panels;
- To develop, integrate, and promote the space-based observational requirements of the user communities carrying out global studies and providing related advice and services;
- To recommend to the space agencies how these requirements may be met (e.g., through such bodies as the Committee on Earth Observation Satellites or the Coordination Group on Meteorological Satellites);
- To facilitate the participation of the global observing communities, in particular in developing countries, through regional activities;
- To identify and evaluate problems, and advocate solutions;
- To report regularly to the JSTC, GOOS, and GTOS SC.

The GOSSP will be the focus for exploiting space systems in meeting the objectives of the global observing systems. The Panel must continually refine, update, and interpret the implications of the requirements of the user communities carrying out global studies, and provide related advice in terms of space instruments and satellite payloads flown by the data providing agencies.

[8] *now the GOOS Steering Committee*

A3.1 International Geosphere-Biosphere Programme (IGBP)

Objectives

To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human activities.

A3.1.1 Global Ocean Ecosystem Dynamics (GLOBEC)

Global Ocean Ecosystem Dynamics (GLOBEC) is a new IGBP Core Project. GLOBEC adds an important dimension to the overall IGBP global change science plan: a focus on marine ecosystems.

The GLOBEC goal is:

To advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems and its response to physical forcing, so that a capability can be developed to forecast the responses of the marine ecosystem to global change.

GLOBEC has four objectives:

- To understand better how multiscale physical environmental processes force large-scale marine ecosystem changes;
- To determine the relationships between structure and dynamics in a variety of oceanic systems which typify significant components of the global ocean ecosystem, with emphasis on trophodynamic pathways, their variability and the role of nutrition quality in the food web;
- To determine the impacts of global change on stock dynamics using coupled physical, biological and chemical models linked to appropriate observation systems and to develop the capability to predict future impacts; and
- To determine how changing marine ecosystems will affect the global Earth system by determining, identifying and quantifying feedback mechanisms.

A3.1.2 Joint Global Ocean Flux Study (JGOFS)

The operational goal for this IGBP Core Project is to improve knowledge of the processes controlling carbon fluxes between the atmosphere, surface ocean, ocean interior and its continental margins, and the sensitivity of these fluxes to climate changes. There is now improved scientific understanding regarding the importance of the oceans as a sink for anthropogenic carbon under present day conditions; however, the future behaviour of the ocean carbon system remains uncertain, and could have a critical effect on the rate of build-up of atmospheric $C0^{2}$.

Objectives

- To determine and understand on a global scale the processes controlling the time-varying fluxes of carbon and associated biogenic elements in the ocean, and to evaluate the related exchanges with the atmosphere, sea floor, and continental boundaries; and
- To develop a capability to predict on a global scale the response of oceanic biogeochemical processes to anthropogenic perturbations, in particular those related to climate change

A3.1.3 Land-Ocean Interactions in the Coastal Zone (LOICZ)

As its name implies LOICZ is the core project of the IGBP that focuses on the area of the earth's surface where land, ocean and atmosphere meet and interact.

The goals of the LOICZ project, as stated in the Science Plan (IGBP,1993) are:

(a) To determine at global and regional scales:
- the fluxes of material between land, sea and atmosphere through the coastal zone
- the capacity of coastal systems to transform and store particulate and dissolved matter
- the effects of changes in external forcing conditions on the structure and functioning of coastal ecosystems;

(b) To determine how changes in land use, climate, sea level and human activities alter the fluxes and retention of particulate matter in the coastal zone, and effect coastal morphodynamics;

(c) To determine how changes in coastal systems, including responses to varying terrestrial and oceanic inputs of organic matter and nutrients, will affect the global carbon cycle and trace gas composition of the atmosphere;

(d) To assess how responses of coastal systems to global change will affect the habitation and usage by humans of coastal environments, and to develop further the scientific and socio-economic basis for the integrated management of the coastal environment.

A3.2 World Climate Research Programme (WCRP)

Objectives

To determine:-

- to what extent climate can be predicted; and
- the extent of man's influence on the climate.

To achieve these objectives, the Programme has undertaken to

- improve the knowledge of global and regional climates, their temporal variations and our understanding of the responsible mechanisms;
- assess the evidence for significant trends in global and regional climates;
- develop and improve physical-mathematical models capable of simulating and assessing the predictability of the climate system over a range of timescales; and
- investigate the sensitivity of climate to possible natural and man-made stimuli and to estimate the changes in climate likely to result from specific disturbing influences.

Annex 3

Relevant Research Projects and their objectives

A3.2.1 Climate Variability and Predictability (CLIVAR) Programme

CLIVAR is a fifteen year long integrated climate programme of the WCRP, to study climate variability and predictability and the response of the Climate system to anthropogenic forcing. CLIVAR has as its objectives:

- to describe and understand the physical processes responsible for climate variability and predictability on seasonal, interannual, decadal, and centennial time scales, through the collection and analysis of observations and the development and application of models of the coupled climate system, in co-operation with other relevant climate-research and observing programs;
- to extend the record of climate variability over the time scales of interest through the assembly of quality-controlled paleoclimatic and instrumental data sets;
- to extend the range and accuracy of seasonal to interannual climate predictions through the development of global coupled models;
- to understand and predict the response of the climate system to the growth of the radiatively active gases and aerosols and to compare these predictions to the observed climate record in order to detect the anthropogenic modification of the natural climate signal.

The CLIVAR program is organized into three component programs:

- CLIVAR-GOALS: A study of seasonal-to-interannual global variability and predictability,
- CLIVAR-DecCen: A study of decadal-to-centennial global variability and predictability, and
- CLIVAR-ACC: A study of the response of the climate system to the addition of radiatively active gases and aerosols to the atmosphere.

CLIVAR-GOALS will examine the variability and predictability of the Global Ocean/Atmosphere/Land System on seasonal-to-interannual time scales. It will build on the successful TOGA program by:

- maintaining the TOGA observing system in the tropical Pacific and further developing the predictive skill for SST and concomitant climate variables in the tropics;
- expanding the study of seasonal-to-interannual variability into the global tropics, including tropical oceans and land masses;
- studying the interaction of monsoons with ENSO with a view towards improving the predictability of both;
- studying the interaction between the tropics and extratropics with the intention of understanding predictability and developing predictive skills for extratropical regions;
- studying the existence of seasonal-to-interannual variability and predictability in the extra tropics locally induced by the oceans, land surface processes, or sea-ice processes.

CLIVAR-DecCen will examine the mechanisms of variability and predictability of climate fluctuations on decadal-to-centennial time scales by:

- describing and understanding the patterns of global decadal-to-centennial variability in the instrumental, paleoclimatic, and model records to the extent possible;
- extending the records of climatic variability by concerted efforts at data recovery, reanalysis of existing atmospheric and oceanic data, finding new paleoclimatic indices, and instituting new oceanographic monitoring sites;
- developing appropriate observing, computing, and data collection and dissemination systems needed to describe, understand, and predict global decadal variability.

It is expected that special regions of the world's oceans (water mass transformation regions and strong boundary currents and return path "choke points") have a large part to play in controlling decadal-to-centennial variability and efforts will be devoted to identifying these specific regions and understanding the mechanisms by which the ocean and atmosphere interact to give this variability.

CLIVAR-ACC will examine the nature of Anthropogenic Climate Change, primarily in a modelling context, by:

- simulating the response of the climate system to the anthropogenic increases in radiatively active gases and aerosols using state-of-the-art coupled atmosphere-ocean-land-cryosphere models;
- identifying the patterns of anthropogenic modification of the natural climate system, both mean and variable;
- using these identifications for interpreting natural climate variability and for detecting the trends of greenhouse warming.

As the CLIVAR program develops, it is intended that the component programs merge and projects be launched that cut across the time scales and component programs. Two CLIVAR Numerical Experimentation Groups are to be formed to coordinate international modelling studies. Strong links will be essential between CLIVAR and other national and international climate research programs, especially IGBP, GEWEX, WOCE and ACSYS as well as with the monitoring programs, GCOS and GOOS.

A3.2.2 World Ocean Circulation Experiment (WOCE)

WOCE arose in 1982 from the inception of the WCRP, the advent of satellites and new *in situ* techniques to observe the oceans, the advances in computer capability and a consensus amongst oceanographers that the time was ripe to turn again to the problems of large scale oceanography. WOCE was established jointly by the CCCO and JSC.

The goals and objectives of WOCE, as set out in the Scientific Plan (WCRP, 1986), remain extant and are:
Goal 1: to develop models useful for predicting climate change and to collect the data necessary to test them.
Goal 2: to determine the representativeness of the specific WOCE data sets for the long-term behaviour of the ocean, and to find methods for determining long-term changes in the ocean circulation.

Within Goal 1 the specific objectives are:
To determine and understand on a global basis the following aspects of the World Ocean circulation and their relation to climate:

1. The large-scale fluxes of heat and fresh water; their divergences over 5 years, and their annual and interannual variability.
2. The dynamical balance of the World Ocean circulation and its response to changing surface fluxes.
3. Components of ocean variability on months to years, mega-metres to global scale, and the statistics on smaller scales.
4. The rates and nature of formation, ventilation and circulation of water masses that influence the climate system on time scales from ten to one hundred years.

In addition to improvements for climate prediction, the WOCE data set and modelling are expected to result in improved global descriptions of circulation.

Within Goal 2 the specific objectives are:

1. To determine the representativeness of the specific WOCE data sets.
2. To identify those oceanographic parameters, indices and fields that are essential for continuing measurements in a climate observing system on decadal time scales.
3. To develop cost-effective techniques suitable for deployment in an on-going climate observing system.

Goal 1, towards ocean model development through improved understanding of the circulation and dynamics, has evolved into the central focus of WOCE. Goal 2 is being addressed through WOCE programmes that sample temporal variability, and through assessment of the observational and modelling strategies being used for Goal 1. Further planning and programmes to achieve Goal 2 are being carried out now outside WOCE; specifically via GOOS and CLIVAR.

Annex 4
Data Category Conventions

The following conventions for defining levels of data and products have been widely used by the atmospheric research community since the Global Atmospheric Research Programme and have been adopted for use by the G3OS. When applied to data from satellites, these conventions should comply with the definitions used by CEOS that are similar but not identical to those given below.

LEVEL 0: Unprocessed instrument data at full space and time resolution with all available supplemental information to be used in subsequent processing appended.

LEVEL I: Instrument readings at full instrument resolution expressed in appropriate units and referred to earth co-ordinates, e.g. radiances, positions of constant level balloons, electrical current, etc.

LEVEL II: Geophysical parameters or environmental observations obtained directly from instruments or converted from Level I data.

LEVEL III: Gridded analyses (spatially or temporally re-sampled data) prepared from Level II data. The re-sampling may include averaging and compositing.

LEVEL IV: Model output products produced from Level ll or Level III data. These often include model-derived parameters such as fluxes.

Levels II, III and IV are often sub-divided into A and B sub-levels.

LEVEL A: These data are usually available in real or near-real time and are subject to strict operational cut-off times. Level A data and analyses are usually subject to operationally driven quality control and are useful for operational purposes and preliminary research.

LEVEL B: These data are normally subjected to rigorous quality assurance procedures and often contain observations that were not available within the operational cut-off times applied to Level A. They are generally more accurate and complete than Level A data because they have the benefit of more data, freedom from rigid production schedules, and utilisation of more elaborate analysis techniques.

Acronyms

ACC	Anthropogenic Climate Change (programme of CLIVAR)
ADCP	Acoustic Doppler Current Profiler
ADEOS	Advanced Earth Observing Satellite
AIM	Atlantic Isopycnic Model
AIMS	Australian Institute of Marine Science
ALACE	Autonomous Lagrangian Circulation Explorer
AMI	Active Microwave Instrument
AMSU	Advanced Microwave Sounding Unit
AOML	Atlantic Oceanographic and Meteorological Laboratory (of NOAA)
Argos	French Data Collection and Location system (on NOAA operational satellites)
ATOC	Acoustic Thermometry of Ocean Climate
ATOVS	Advanced TIROS Operational Vertical Sounder
ATSR	Along Track Scanning Radiometer
AUV	Autonomous Underwater Vehicle
AVHRR	Advanced Very High Resolution Radiometer
AVISO	Archiving, Validation and Interpretation of Satellite Data in Oceanography
AVNIR	Advanced Visible and Near-Infrared Radiometer
BOAT	Bulletin Océan Atlantique Tropical
BODC	British Oceanographic Data Centre
BoM	Bureau of Meteorology (of Australia)
BSEP	Black Sea Environmental Programme
CASI	Compact Airborne Spectral Interferometry
CBA	Cost Benefit Analysis
CCCO	Committee on Climate Changes and the Ocean (of IOC and SCOR)
CEOS	Committee on Earth Observation Satellites
CERSAT	Centre ERS d'Archivage et de Traitment
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
CLIPS	Climate Information and Prediction Services
CLIVAR	Climate Variability and Predictability (programme of WCRP)
CMM	Commission for Marine Meteorology (of WMO)
CoMSBlack	Co-operative Marine Science Program for the Black Sea
CPC	Climate Prediction Center
CPR	Continuous Plankton Recorder
CSA	Canadian Space Agency
CTD	Conductivity/Temperature/Depth device
DBCP	Data Buoy Co-operation Panel
DecCen	Decadal-to-Centennial (programme of CLIVAR)
DIMS	Data and Information Management Service (of GOOS)
DIS	Data and Information System
DMDB	Delayed Mode Data Base
DMSP	Defense Meteorological Satellite Program
DNA	Designated National Agency
DORIS	Determination d'Orbite et Radiopositionement Integré par Satellite
DRIBU	Drifting Buoy code
ECMWF	European Centre for Medium-range Weather Forecasts
EEZ	Exclusive Economic Zone
EGOS	European Group on Ocean Stations
ENSO	El Niño – Southern Oscillation
EO	Earth Observation
EPA	Environmental Protection Agency
ERS	European Research Satellite
EU	European Union
EUREKA	European Research Programme
EuroGOOS	European Association for the GOOS
FAO	Food and Agriculture Organization
FCCC	Framework Convention on Climate Change
FGGE	First GARP Global Experiment
FNOC	Fleet Numeric Oceanographic Center
FOAM	Forecasting Ocean Atmosphere Model
FRAM	Fine Resolution Antarctic Model

Annex 5
Acronyms

G3OS	GCOS/GOOS/GTOS
GAIM	Global Analysis, Interpretation and Modelling (IGBP Task Force)
GARP	Global Atmosphere Research Programme
GATE	GARP Tropical Experiment
GCM	General Circulation Model
GCOS	Global Climate Observing System
GCRMN	Global Coral Reef Monitoring Network
GDP	Global Drifter Programme
GEF	Global Environment Facility
GEOSAT	Geodesy Satellite
GER	Global Environmental Research
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIM	Global Isopycnic Model
GIPME	Global Investigation of Pollution in the Marine Environment
GIS	Geographic Information System
GLI	Global Imager
GLOBEC	Global Ecosystem Experiment
GLOSS	Global Sea Level Observing System
GMS	Japanese Geostationary Meteorological Satellite
GNP	Gross National Product
GOALS	Global Ocean Atmosphere Land System (programme of CLIVAR)
GODAE	Global Ocean Data Assimilation Experiment
GODAR	Global Ocean Data Archaeology and Rescue
GOES	Geostationary Operational Environmental Satellite
GOLDIS	GCOS On-Line Data and Information System
GOOS	Global Ocean Observing System
GOSSP	Global Observing System Space Panel
GPA/LBA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
GPO	GOOS Project Office
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GSC	GOOS Steering Committee
GTOS	Global Terrestrial Observing System
GTS	Global Telecommunication System
GTSPP	Global Temperature and Salinity (Pilot) Programme
HAB	Harmful Algal Bloom
HDP	Human Dimensions of Global Environmental Change Programme
HF	High Frequency
HIRS	High Resolution Infrared Sounder
HOTO	Health of the Ocean
IABP	International Arctic Buoy Programme
IAEA	International Atomic Energy Authority
IBPIO	International Buoy Programme for the Indian Ocean
ICES	International Council for the Exploration of the Sea
ICLARM	International Center for Living Aquatic Resources Management
ICRI	International Coral Reef Initiative
ICSU	International Council of Scientific Unions
ICZM	Integrated Coastal Zone Management
IDPSS	IGOSS Data Processing and Services System
IGBP	International Geosphere-Biosphere Programme
I-GOOS	Intergovernmental Committee for GOOS
IGOS	Integrated Global Observing Strategy
IGOSS	Integrated Global Ocean Services System
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
IOS	IGOSS Observing System
IPAB	International Programme for Antarctic Buoys
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
IRI	International Research Institute

IRS	Indian Research Satellite
ISABP	International South Atlantic Buoy Programme
ISRO	Indian Space Research Organisation
IT	Information Technology
ITA	IGOSS Telecommunication Arrangement
IUCN	World Conservation Union
JAMSTEC	Japan Marine Science and Technology Center
JDIMP	Joint Data and Information Management Panel
JGOFS	Joint Global Ocean Flux Study (of IGBP)
J-GOOS	Joint Scientific and Technical Committee for GOOS
JMA	Japan Meteorological Agency
JSC	Joint Scientific Committee (of WMO and ICSU)
LANDSAT	Land Satellite
LMR	Living Marine Resources
LOICZ	Land-Ocean Interactions in the Coastal Zone (of IGBP)
MAESTRO	Marine Information System to Support Offshore Operations
MARPOLMON	Marine Pollution Monitoring
MAST	Marine Science and Technology Programme
MEDS	Marine Environmental Data Service
METEOSAT	European Geostationary Meteorological Satellite
MIM	Marine Information Management
MPI	Max Plank Institute
MSU	Microwave Sounding Unit
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NEAR-GOOS	North East Asian Regional GOOS
NGO	Non Governmental Organisation
NMC	National Meteorological Centre
NOAA	National Oceanographic and Atmospheric Administration
NOC	National Oceanographic Centre
NODC	National Oceanographic Data Centre
NRC	National Research Council
NSCAT	NASA Scatterometer
NWP	Numerical Weather Prediction
OCA/PAC	Oceans and Coastal Areas Program Activity Center
OCCAM	Ocean Circulation and Climate Advanced Model
OCTS	Ocean Colour and Temperature Scanner
OECD	Organisation for Economic Co-operation and Development
OOPC	Ocean Observation Panel for Climate
OOSDP	Ocean Observing System Development Panel
OSE	Observing System Experiment
OSSE	Observing System Simulation Experiment
OTIS	Optimum Thermal Interpolation system
PAH	Polycyclic Aromatic Hydrocarbons
PALACE	Profiling Autonomous Lagrangian Circulation Explorer
PCB	Poly-Chlorinated Biphenyls
PICES	North Pacific Marine Sciences Organization (Pacific ICES)
PIRATA	Pilot Research Moored Array in the Tropical Atlantic
PMEL	Pacific Marine Environmental Laboratory (of NOAA)
PMOC	Principal Meteorological or Oceanographic Centre (of the DBCP)
PNA	Pacific North American (teleconnection pattern)
PODAAC	Physical Oceanography Distributed Active Archive Center
PSMSL	Permanent Service for Mean Sea Level (of GLOSS)
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
RNODC	Responsible National Oceanographic Data Centre
RSA	Russian Space Agency
RTDB	Real Time Data Base
S&T	Science and Technology

Annex 5
Acronyms

SAHFOS	Sir Alister Hardy Foundation For Ocean Science
SAR	Synthetic Aperture Radar
SCOR	Scientific Committee on Oceanic Research (of ICSU)
SeaWiFS	Sea-viewing Wide-Field Sensor
SECAMP	South East Asian Centre for Atmospheric and Marine Prediction
SIT	Strategic Implementation Team (for the IGOS)
SLP	Sea Level Pressure
SME	Small to Medium sized Enterprise
SOAP	Service Operationel d'Analyse et Provision
SOLAF	Surface Ocean Lower Atmosphere Feedbacks
SOLAS	International Convention for the Safety of Life at Sea
SOOP	Ship Of Opportunity Programme
SPACC	Small Pelagic Fishes and Climate Change
SPOT	Système Probatoire d'Observation de la Terre
SSM	Special Sensor Microwave
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
TAO	Tropical Atmosphere Ocean (array of buoys)
TEMA	Training, Education and Mutual Assistance (of IOC)
TIP	TAO Implementation Panel
TIROS	Television and Infrared Operational Satellite
TOGA	Tropical Ocean Global Atmosphere (experiment of WCRP)
TOPEX/ Poseidon	Joint US/French Ocean Topography Experiment
TOPS	Thermodynamic Ocean Prediction System
TOVS	TIROS Operational Vertical Sounder
TRITON	Triangle Trans-Ocean Buoy Network
U.S.	United States
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UOP	Upper Ocean Panel (of CLIVAR)
USN	United States Navy
VOS	Voluntary Observing Ship
WCASP	World Climate Applications and Services Programme
WCP	World Climate Programme
WCRP	World Climate Research Programme
WDC	World Data Centre (of ICSU)
WESTPAC	Western Pacific (IOC region)
WHO	World Health Organization
WIOMAP	Western Indian Ocean Marine Applications Project
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment (of WCRP)
WOCE-AIMS	Analysis, Integration, Modelling and Synthesis phase (of WOCE)
WWW	World Weather Watch
XBT	Expendable Bathythermograph
XCTD	Expendable Conductivity/Temperature Device