Global Ocean Observing System

An Indian Ocean Observing Strategy

"A Partnership of Agencies and Institutions supporting sustained observations in the Indian Ocean region."

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Introduction

This Strategy document makes a case for the establishment of an Indian Ocean Climate, Open Ocean and Coastal Ocean observing systems under the umbrella of the Global Ocean Observing System (GOOS) in partnership with research programs. It begins by identifying the importance of the Indian Ocean and the difficulties that must be overcome to establish cooperation in the region. Other GOOS regional organizations are identified to provide models for organization, and this is followed by a suggestion of a model appropriate for the Indian Ocean. Finally, background on the Intergovernmental Oceanographic Commission's (IOC) involvement in Indian Ocean marine science development is given to point out the region's historical association with the IOC and to provide evidence of tangible building blocks for further development. The aim of this Strategy document is to provide a framework for enhancing the observing system in the Indian Ocean, and to serve as a catalyst for development. The Strategy document avoids being prescriptive but encourages individual nations or regional groupings to add to our knowledge of the Indian Ocean in an incremental and collective manner that will engender mutually beneficial results.

I. Importance of Observing the Indian Ocean

- **Why Observe the Oceans?**

The oceans are of central importance to the life system of the earth. They regulate global climate by redistributing the heat and freshwater across the geosphere. They also sustain an important fraction of global living and non-living resources and, in contemporary times, are also the largest reservoirs for man-made pollutants, with a phenomenal assimilative capacity. Since time immemorial, the oceans and their seas have thus played a crucial role in the evolution and spread of civilizations across the globe.

Influence of oceanic processes on weather and climate has been known for quite some time. Our abilities to forecast weather and global climate changes, thus pre-empting disastrous effects of events such as cyclones and El Nino, remain contingent on our ability to observe the changes in ocean processes at spatial and temporal scales with a greatest possible resolution. Ocean circulation does not recognize national boundaries and knowledge is building up to show that changes in weather in one part of the globe can be remote effects of oceanic processes at other parts. Thus the need to observe ocean parameters in a co-ordinated way, across national boundaries, becomes critical. While some stocks of living marine resources such as benthic organisms are local or national in distribution, several others such as the straddling stocks of tunas or sharks are regional or even global in distribution. Their trans-national nature becomes even more striking when several nations share common sea areas, as in the Mediterranean or the North Sea. Oceanic and coastal circulations also actively transport pollutants across geopolitical boundaries, with sources and impacts separated on various space and time scales. This leads to the growing recognition that it is impossible, politically, logistically and economically, for any one nation to collect all the information it needs for national prosperity and environmental security. All these are strongly arguments for synoptic and sustained observations of oceans and their properties at local, regional, and global scales.

GOOS (Global Ocean Observing System) responds to this need. It is envisioned as an operational, global network that systematically acquires and disseminates data and data products on past, current and future states of the marine environment to serve the needs of many users ranging from governments and industries to scientists, educators, non-governmental organizations and public. The observing system is being developed in two related and convergent modules: (1) a global ocean module concerned primarily with changes in the ocean-climate system and improving marine services including hazard warnings and (2) a coastal module concerned with the effects of large scale changes in the ocean-climate system and of human activities.

The coastal module thus introduces a human dimension to GOOS. The present population of coastal areas exceeds the total global population of just 50 years ago, with 50% of the human population living within 150 km from the coast and nearly 40% within 100 km. Such a rapid growth in population pressure had altered substantially the value of ecosystem services and goods in the coastal zone. Over fishing is already a problem with many marine stocks; physical alterations to coastal habitats increasing the susceptibility of coastal populations to flooding and erosion have become more common; inputs into the sea of untreated sewage are major sources of nutrients that cause coastal eutrophication and of human pathogens that increase human health risks; introduction of non-native species that affect local flora and fauna and eventually the local fisheries, are only some examples. The costs of environmental degradation and the benefits derived from successful mitigation are becoming increasingly clear. Without an integrated and sustained observing system to assess and predict critical changes in the coastal environment, our ability to sustain healthy ecosystems and their resources, including the vast reservoir of bioactive molecules harboured by coastal flora and fauna, will continue to be compromised.

Our abilities to forecast weather, sustainably use the marine resources and maintain the ecosystem values of the marine environment are effectively dependent on rapid detection and timely prediction of the changes in ocean processes, which in turn calls for an observing system that is cost-effective and responds to the needs of variety of users. This requires an unprecedented level of regional and global co-operation. Nations must therefore seek appropriate regional cooperation in order to ensure that the information they require is gathered and accessible. This regional approach - share obligations and co-sponsor sophisticated equipment and quality-assured observations – would be the hallmark of GOOS Regional Associations (GRAs) from which the truly Global Ocean Observation System would mature.

A major goal of GOOS is to reduce the time required to acquire, process and analyze data of known quality so that delivery of environmental data and information is made to the end –users within time scales on which environmental decisions and predictions are made. A data management and communication system that provides rapid access to data and information will be the 'lifeline' of the observing system. In accordance with GOOS design principles, the GRAs will need to develop a hierarchical, distributed network of local, national, regional organizations feeding eventually into a global framework, that use common standards and protocols for quality control, access to and exchange of data and archival.

- **Indian Ocean Characteristics**

The Indian Ocean is the third largest ocean in the world and occupies, excluding the marginal seas, an area of about 73.44 million km^2 between its northernmost extremity and 40ºS. It encompasses 21% of the world's sea area and 14% of the earth's surface. The Indian Ocean countries comprise of 36 littoral and 11 hinterland states, together accounting for 30% of the earth's population. Unlike the Pacific or Atlantic Ocean, it is landlocked to the north.

One of the interesting features of the Indian Ocean is that in its northern region the surface circulation reverses every half-year. The climate is thus dominated by the monsoon system (northeast monsoon (December to April), and the stronger southwest monsoon (June to October)) that drives the agrarian economy of most of the Indian Ocean countries. Year-to-year variations of sea temperatures across the Indian Ocean are associated with rainfall over Australia and Africa, and driven by interactions between large-scale ocean waves and the Pacific El Nino. These cause a zonal seesaw of the thermocline and an associated dipole pattern in the atmosphere that has received attention in recent years. This zonal see-saw changes the climate of surrounding countries, and is a common problem binding IO countries together. The dipole may act to modulate the global ENSO phenomena in ways that are as yet unknown.

The Indian Ocean region is also a significant contributor to the production of living marine resources with an estimated annual yield of 8 million tons of capture fisheries and 23 million tons of culture fisheries, equivalent respectively to 10 and 90 % of world production. The tropical countries of the Indian Ocean are also known for the high coastal and marine biodiversity they sustain, with countries like India being regarded as mega-biodiversity countries. The tropical nature also endows most Indian Ocean countries with vast stretches of sensitive coastal marine ecosystems. The coral reefs of the Indian Ocean spread over 1,85,000 km^2, close to about 30 % of the global reef cover. The mangroves spread over 37,000 km^2 or about 10% of the world mangrove area, with the world's second largest mangrove forest (Sunderbans) lying in the Gangetic delta of Indian sub-continent.

The 30% of the earth's population living within 14% of the earth's surface, with about a third of them within 100 km from the sea, exert a pressure on the health of the coastal seas. A conservative estimate places the entry of sewage into the Indian Ocean at about 57 million liters per day, most of them untreated. Rapid industrialization of the coast along with the growth of mega cities, has added another dimension to the pollution. With a thumb rule ration of 10:1 between sewage and industrial effluents, it is likely that at least 6 million liters per day of industrial effluents would be entering the coastal zone. This does not include river-transported sewage and effluents from hinterland, pesticide and fertilizer residues and solid wastes. The enormity of the pressure on the health of the coastal seas cannot escape attention and concern.

- **Economic Factors**

The Indian Ocean is important from an economic perspective. It provides major sea routes connecting the Middle East, Africa, and East Asia with Europe and the Americas. It carries sea traffic associated with petroleum exploration and petroleum products from the oilfields of the Persian Gulf and Indonesia. An estimated 40% of the world's offshore oil production comes from the Indian Ocean, with more than 50% of the transport occurring through the Arabian Sea region.

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Large reserves of hydrocarbons are being tapped in offshore from the Persian Gulf, and off India and western Australia. Its living marine resources are of growing importance to the bordering countries for domestic consumption and export. Fishing fleets from Russia, Japan, South Korea, and Taiwan operate in the Indian Ocean, mainly searching for shrimp and tuna. Beach sands rich in heavy minerals are actively exploited by bordering countries, particularly India, South Africa, Indonesia, Sri Lanka, and Thailand. Tourism is a substantial industry around the margins, particularly where fringing coral reefs occur. All of this economic activity is subject to monsoon troughs, floods, droughts and tropical cyclones that frequent the coastal regions, that are, in turn, influenced by the mid-ocean and the climate generated by it.

The importance of understanding, monitoring and predicting variations in the Indian Ocean is underscored by the human, environmental and economic factors cited above. Aside from these factors, which are all coastal or open ocean, the ocean's influence on climate is also felt in the hinterland, for example in the supply of fresh water, the productivity of agriculture, and the demand for energy.

II. Regional Issues

Historically, knowledge of the Indian Ocean has been limited relative to the Pacific and Atlantic. The Indian Ocean is poorly observed and contains few permanent moorings in the equatorial zone, where strong eastward currents and coupled intra-seasonal waves are prevalent. A tropical ocean observing system has been implemented in the Pacific and Atlantic basins, however the lack of data in the Indian Ocean means that numerical prediction models cannot be adequately initialized. Sustained observing and monitoring combined with modelling and analysis will produce marine data and services that people need for decision-making (e.g. where to route ships; what environmental stresses can be expected at the coast, what crops to plant and when, etc.). Application of the data and provision of information and services to governments and the public will result in improved management, quality of life, and improved access to the resources contained within the Indian Ocean.

- **Regional Problems**

Regional marine science cooperation in the Indian Ocean has been in general difficult to initiate and sustain. There are a number of reasons for this. Many of the countries of the region have limited resources and the extra funds required to study and monitor their coastal seas and the adjacent oceans are a lower priority. Another obstacle is the priority accorded to strategic considerations and national security that hamper smooth mechanisms for sharing information on the marine environment, most of which could be unrelated to defense issues at all. Within individual countries different agencies may have different objectives, and priorities and mechanisms are missing that would allow cooperative activities. Added to all these is the prevailing mistrust between nations with regard to marine science and the gulf between developed an developing countries. There have been several abortive attempts at cooperation but little implementation, except perhaps some capacity building activities.

Under the umbrella of the IOC the countries of the region have established two regional committees for the purpose of organizing themselves. The regional committees provide a useful mechanism for the region with respect to representation at IOC executive body meetings for purposes of voting and decisions on budget allocations. As mechanisms for cooperation in marine science activities and GOOS they have not been effective, largely for the reasons cited above. Following the PACSICOM meeting in 1998, GOOS-Africa was formed to look after coastal affairs, including the sea-level network, remote sensing and shelf circulation modelling. Such committees are intended to act as mechanisms for sharing what is learned and enhancing potential benefits.

- **Regional Success**

The most successful attempts at conducting regional Indian Ocean marine scientific research have been when multi-national efforts are planned with active and full participation of academic and operational institutions from both within and outside the region. The first example is the International Indian Ocean Expedition, which was conducted during 1959-1965. It involved more than forty research vessels belonging to thirteen countries. Data were collected in many marine science disciplines, as reflected in the hundreds of papers and numerous atlases published. National and world data centers were established, notably the National Institute of Oceanography in Goa. Computers were used for data logging and new oceanographic instruments were introduced. The IIOE was coordinated by the IOC and included most of the Indian Ocean countries.

The Joint Global Ocean Flux Study (JGOFS) involved cruises in the Arabian Sea by six countries including Germany, India, Netherlands, Pakistan, UK and USA during 1992-1997. Its goal was to understand the processes controlling, regional to global and seasonal to interannual fluxes of carbon between the atmosphere, Surface Ocean and ocean interior, and their sensitivity to climate changes.

Perhaps the most sustained and comprehensive effort to study and understand the ocean circulation and physical parameters of the region was the World Ocean Circulation Experiment (WOCE). WOCE is a part of the World Climate Research Program (WCRP) sponsored by IOC, WMO and ICSU. It has used resources from nearly 30 countries to make ship-based and satellite observations of the global ocean between 1990 and 1998 and to observe poorlyunderstood but important physical processes. The Analysis Interpretation Modeling and Synthesis (AIMS) phase will end in 2002.

Much still remains unclear about mechanisms by which the ocean affects regional and global climate or how far the living resources and the health of the seas can remain unimpaired. Therefore, a successful program for the Indian Ocean must include a strong synergy between IOC initiatives for GOOS and the gradual and incremental build-up of sustained observations by international research programs. Institutional involvement from within the region has to be carefully thought out. There must be active and full participation of both the academic and government sponsored oceanographic institutions from countries in the region. Also the mandates of organizations must be evaluated. For example, NIO in India is at the forefront of national oceanographic R&D activities, although it has a limited mandate for regional/global initiatives.

In taking forward a successful program for the Indian Ocean, the history of past successes combined with the reality of present local capabilities suggests that active and full participation of the academic and oceanographic institutions from both within and outside the region could be most rewarding.

- **Other Regions' Approaches to Organizing GOOS**

The development of GOOS regionally has varied depending on the interests of the countries/agencies involved, consideration of funding opportunities, pre-existing organizational structures and various geo-political criteria. EuroGOOS is the most advanced of GOOS regional organizations. It is structured on the basis of "agencies" cooperating as opposed to "countries". Sub-regions of EuroGOOS have developed their own pilot projects and observing activities under the umbrella of EuroGOOS, such as the Mediterranean Forecasting Project, and the Baltic Ocean Observing System, while adhering to GOOS principles and guidelines. EuroGOOS has benefited from having an economically viable membership. MedGOOS is another organization based on participation of agencies as opposed to governments and it has progressed fairly well.

NEAR-GOOS (North East Asia Regional GOOS) was formed to facilitate the exchange of data between Japan, the Republic of Korea, the Russian Federation and China, especially in the Sea of Japan. The countries participating are motivated by a common interest in understanding and acquiring data on the physical parameters of the area for practical applications associated with shipping, fishing, etc. Academic institutions are involved along with government agencies. Japan funds a sizeable research programme directed to improving GOOS activities in the region, largely seawards of Japan. The NEAR-GOOS region may expand in this direction.

PacificGOOS is fairly new with a history of two workshops to build capacity within the region and to identify pilot projects. It is also involved in the SEREAD project designed as a secondary school educational programme associated with the deployment of Argo floats in the region. It is identified because it is an example of an organization based on cooperation amongst existing regional organizations in the Pacific, coupled with organizations/agencies from outside the region that have interest in the region. The concept of membership from outside the region is being suggested for the Indian Ocean in order to attract scientific and funding support.

There are other regional GOOS activities at various stages of development throughout the world, e.g. Black Sea GOOS; IOCARIBE-GOOS in the Caribbean. There is no consensus of opinion or historical record to suggest what type of organization might work best for a particular region. Purposely, very few constraints have been placed on how regions organize themselves to participate in GOOS. Nevertheless some basic rules have been devised by the GOOS Steering Committee, as contained in the document on "Regional Policy for GOOS" endorsed by the fifth session of the IOC-WMO-UNEP committee for GOOS in June 2001.

Duplication of organizations such as EuroGOOS and NEAR-GOOS would be difficult in the Indian Ocean since the region does not contain countries with the economic capacity to fully sustain a regional observing program. Countries instead will have to contribute in whatever way they can and depend on international research and development programs and support from agencies such as the Global Environmental Fund and World Bank.

III. IOC's Involvement

- **General**

The IOC was created in 1960 to help nations cooperate in understanding the oceans and forecasting their behavior. One of its first missions was the now historic International Indian Ocean Expedition completed three decades ago. The IOC has supported a wide range of projects and activities in the region over the years; for example the World Ocean Circulation Experiment (WOCE), JGOFS (Joint Global Ocean Flux Study), IODE (International Oceanographic Data and Information Exchange program), ICAM (Integrated Coastal Area Management), GCRMN (Global Coral Reef Monitoring Network), and others. The IOC is informed about the needs of many of the countries surrounding the Indian Ocean for projects or for capacity building through two regional bodies, the IOC regional committee for the Central Indian Ocean (IOCINDIO) and the IOC regional committee for the north and central Western Indian Ocean (IOCINCWIO). These bodies meet about every 4 years.

In recent years the IOC has been working with countries of the Indian Ocean region in the development of the Global Ocean Observing System GOOS, and through that contributing to the Global Climate Observing System (GCOS) of which GOOS forms the ocean component. In 1997, a GOOS Capacity Building workshop was convened in Goa, India with the objective of explaining how GOOS operates and to identify potential pilot projects. Although the workshop was well attended and several project ideas were tabled, direct follow-up was lacking.

More recently in March 2000, at the IOCINDIO meeting in Teheran, GOOS was discussed and plans were made to develop capacity building in the region. As yet there has been no follow-up GOOS activity apart from continued development of the storm surge proposal.

In 1999, the IOC in partnership with the Department of Commerce and Trade, Western Australia and the Bureau of Meteorology of Australia established the IOC Perth Regional Programme Office. The primary objective of the Office is to develop GOOS in the South Pacific, Indian Ocean, Southern Ocean and Australia. The Perth Office will provide linkages through the IOC to the GOOS intergovernmental structure and to other organizations interested in developing and supporting GOOS.

The series of meetings in Perth during November 2000, including the SOCIO workshop, are seen as contributing to the establishment of a sustained observing activity for the Indian Ocean. Assisting the countries of the Indian Ocean region on preparing and organizing an observing organization is central to the role of the Office. Workshops have been convened in WA by the Perth Office to develop a WAGOOS activity beneficial to WA. Expertise developed in WA can be used to promote development of GOOS in the Indian Ocean and Pacific regions, particularly in capacity building. Also, modelers can use any coastal observations taken off WA.

The needs of the African coastal countries for integrated coastal area management (ICAM) were addressed by the IOC through the Pan-African Conference on Integrated Coastal Management (PASICOM) at Maputo in July 1998. It identified the need for extensive capacity building, and also for the development of GOOS in support of ICAM. As a consequence the attendees at the meeting agreed to form GOOS-Africa, a committee to stimulate and coordinate GOOS developments continent-wide. They identified four main priorities for the immediate future: (i) building an Africa-wide network of tide gauges and training people to use them; (ii) providing access to and training in the use and application of remotely sensed data from satellites; (iii) building an Africa-wide network of national oceanographic data centres, and training people to work them; and (iv) providing an adequate electronic communications infrastructure, to facilitate data exchange. The last two are being implemented through ODINAFRICA (see below). Proposals for the first two are in preparation. A second meeting of GOOS-Africa took place in Nairobi in November 2001. Several pilot projects were identified for coordination and enhancement: the coastal sea level network, increased use of remote sensed data, and regional scale modeling. There will be a need to distinguish a coastal component addressed by GOOS-Africa, a mid-ocean component under the auspices of IO-GOOS, and a SEA-GOOS in respect of ocean monitoring activities in South East Asia. Membership of IO-GOOS needs to incorporate representatives of these adjacent organizations.

IV. Potential GOOS Initial Observing System

Observational Elements

- **IOC Global Sea-Level Observing System (GLOSS)** -Monitoring sea-level variation and rise. Thirteen GLOSS stations have been established within the framework of the WMO / IOC Tropical Ocean and Global Atmosphere (TOGA) programme of the World Climate Research Programme (WCRP) since 1996.
- **WMO/IOC Ship Of Opportunity Programme (SOOP)** – Monitoring of the upper ocean temperature along specified routes at pre-determined sampling intervals. A few lines as recommended by the World Ocean Circulation Experiment (WOCE) are being implemented with participation of countries in the WIO.
- **WMO/IOC Data Buoy Cooperation Panel (DBCP)** – This panel coordinates the deployments of drifting buoys collecting Surface Ocean and marine meteorological data. Its Indian Ocean action group is the International Buoy Programme for the Indian Ocean (IBPIO). The DBCP will next meet in Perth in October 2001.
- **WMO Voluntary Observing Ship Network** - Collects marine meteorological data from commercial ships along trade routes.

Regional Elements

- **ODINAFRICA:** An IOC program to foster cooperation in data and information exchange in Africa.

- **GOOS AFRICA**: A newly formed alliance of African experts and institutions intended to uplift coastal oceanographic observations and applications.

- **IOCINCWIO:** A regional committee of the IOC that serves as a forum for cooperation.

- **IOCINDIO:** A regional committee of the IOC that serves as a forum for cooperation.

- **WAGOOS:** A Western Australia initiative to generate cooperation in GOOS amongst government, industry and academia. A proposal is being developed to link this initiative with GODAE focusing on applications and regional modeling.

Pilot Projects

- **Storm Surge Proposal:** IOC has been working with WMO and other partners to develop a project for a storm surge warning system for the northern part of the Indian Ocean which is a contribution to coastal GOOS. The project calls for instrumentation and monitoring to provide storm surge warnings to the local populations with potential application to GOOS. IOC and WMO are persuading the member states to give high priority to the project in national planning and submit it to the funding agencies.

- **WIOMAP**: The Western Indian Ocean Marine Applications Project will monitor the coastal impacts of severe weather events and improve knowledge and prediction of marine resources. WIOMAP will enhance the marine meteorological network in the tropical western Indian Ocean through the provision of additional observing capability; coordinated through local application centers where communications infrastructure and technical expertise will be upgraded.

- **I-MAP**: The Indian Ocean Moored Array Project will monitor sub-surface ocean conditions and surface fluxes around the western center of action of the so-called Indian Ocean dipole. This will be done through a multi-element array of TAO moorings. I-MAP will ensure that ocean observations are sustained and utilized in data assimilation and modeling activities. This array is needed to complete the global tropical ocean-observing network, to improve climate predictions and identify how the Indian Ocean links with the ENSO phenomena.

Pre-operational projects

- **Argo**: Argo is a revolutionary concept that enhances the real-time capability for measurement of temperature and salinity along the reference level velocities through the upper layer of the ocean and it contributes to the global description of the seasonal and inter-annual variability of the upper ocean thermohaline circulation. Under a unique internationally coordinated project, it is envisaged to establish a global array of 3000 floats by the year 2005 (at a spatial resolution of 3 degrees lat. x 3 degrees long.) through the collective participation and contribution from various countries. It is estimated that 440 floats are needed for the Indian Ocean with several countries already committing to providing floats including India, Australia, France, United States, Japan, Germany and the United Kingdom.

- **GODAE:** Is an experiment in global ocean state estimation, with applications ranging from the provision of boundary conditions for coastal prediction systems to initialization of climate models. Its overall aim is to demonstrate the viability, feasibility and practicality of operational oceanography. Argo floats in the Indian Ocean will contribute to GODAE as well as VOS, SOOP, the Trition Array and satellite measurements.

- **Triton Array:** Two Japanese moored buoys in the eastern Indian Ocean that currently contribute surface and sub-surface data for GODAE from TAO moored platforms. Importantly, they will monitor the eastern center of action of the Indian Ocean dipole, whilst I-MAP monitors the western center.

- **Indian Met-ocean buoys:** In equatorial region of Indian Ocean with data available to the wider oceanographic community. This data will underpin the Storm Surge proposal in the Bay of Bengal.

Data Management

- **IOC Regional Co-operation in Scientific Information Exchange in the Western Indian Ocean (RECOSCIX) –** Assistance from the Belgian and Flanders governments to establish a marine scientific information exchange network in the WIO region with a Regional Dispatch Centre (RDC) in Mombassa as its central node.

- **IOC Oceanographic Data and Information Network in East Africa (ODINEA)** – To encourage the use of standard methods for data collection and storage in the region and develop capacity for the preparation of data products for scientists and policy-makers. The initial thrust is to establish National Oceanographic Data Centers (NODC). ODINEA is now part of an Africa-wide initiative-ODINAFRICA.

- **Global Oceanographic Data and Archaeology and Rescue (GODAR) Project -** IOC'S International Oceanographic Data and Information Exchange (IODE) Programme has taken steps to help the countries of the region rescue marine data trapped in various archives. A GODAR meeting was held in Goa in December 1994.

Operational systems

- **GCRMN** (Global Coral Reef Monitoring Network): The network manages, monitors and undertakes training concerning coral reefs in the Indian Ocean

- **Satellites:** The following operational satellites are providing oceanographic data for the Indian Ocean at present. The use of satellite data in this vast region is essential to accomplish the required coverage.

Operational Ocean Satellites as of 2002:

- Altimeter: Sea Surface Height-Ocean Circulation
US/French Topex Poseiden
ESA's ERS 2

- Scatterometer: Global Near Surface Vector Winds/Air-Sea Interaction/Ice
ESA's ERS 2 (C-Band)
US QuikSCAT (~Ku-Band)

- Synthetic Aperture Radar: Sea Ice, Wind/Wave/Current Interactions and Coastal Ecology
ESA's ERS 2 (C-Band)
Canadian/US Radarsat-1 (C-Band)

- Ocean Color: Ocean Biology (Productivity) and Coastal Pollution
India's IRS-P3 (MOS)
US Seawifs
Taiwan's Rocsat-1
India's IRS P4 (OCM)
US Terra (MODIS)
Korea's KOMPSAT

- Passive Microwave Spacecraft: Sea Ice/Scalar Surface Wind and Total Water Vapor
US DMSP 5D2 (SSM/I)
Japan/US TRMM (TMI)
India's IRS-P4 (MSMR)
US DMSP 5D-3 (SSMIS)

US Terra (MISR)

- Visible/Infrared Low-Resolution: Sea Surface Temperature/Sea Ice
US NOAA TIROS/NEXT AVHRR
US DMSP 5D-1 (OLS)
Japan's MOS-1A (VTIR)
Japan's MOS-1B (VTIR)
ESA's ERS-1 (ATSR-1)
ESA'S ERS-2 (ATSR-2)
Japan/US TRMM (VIRS)
US TERRA (EOS-AM1) MODIS

- Visible/Infrared Medium Resolution: Coastal Ecology and Monitoring/Coral Reef Research
US Landsat 5
US Landsat 7
France Spot 1
France Spot 2
India IRS-1B
India IRS-1C
India IRS-1D
China/Brazil CBERS1

- Visible/Infrared High-Resolution: Mapping, Monitoring and Research
Space Imaging's IKONOS-2

V. Indian Ocean GOOS Proposal

- **Introduction**

The Indian Ocean – GOOS proposal that follows identifies an "organizational" framework for developing an observing system[s] for the Indian Ocean using a basin-scale approach involving contributors and participants with common interests.

The observing system will comprise three basic components:

(i) A data collection subsystem;
(ii) A data and information management subsystem;
(iii) A modeling and applications subsystem for the development of products and services.

Much of the system needs to be regional, and individual nations with institutional capabilities will be in a position to lead this regional approach. The system does not have to be complex. Many parts of it already exist, as listed above, and what is required is an integrated approach to make more cost-effective use of the observations. A major bias towards physical parameters is evident and an initial analysis of capabilities and needs will identify the geographic or technical gaps in the present coverage of observations, both in physical and non-physical parameters. Following this identification, regional discussions can identify ways to improve the coverage. The level of contributions can and will differ between nations, depending on national perceptions and capacities, but this will be in keeping with the spirit of oceanographic collaborations worldwide, where understanding the ocean and its sustainable usage transcends many inequalities.

- **Indian Ocean GOOS [IO-GOOS]**

The most unique aspect of IO-GOOS [which term will used until the organization selects a name] will be its policy of open membership to all interested in understanding the Indian Ocean and willing to share such knowledge and information. Thus, there will be “Regional” members and “Global” members. This will be of importance in the development of climate and marine services. Members could be in the employ of their governments, or could be staff of autonomous agencies, national agencies, academic institutions, data centers, scientific institutions, intergovernmental committees and user groups. All participants however will be referred to as “Members”, and the common denominator will be an interest and ability to contribute to Indian Ocean monitoring, assessment, modelling, product development and use.

GOOS strategic planning is following a two-pronged approach: tropical basin [global] and coastal. The global aspect [climate] is highlighted in this paper making it relevant to the SOCIO workshop [Workshop on Sustained Observations for Climate of the Indian Ocean] that was held in Perth, Australia in December 2001. The coastal module of GOOS is being constructed as a federation of local–national subsystems, with needs for both general [wind, temperature, and currents] and region-specific observations. Each subsystem will have its own special requirements; however, it is recognized that they will benefit from the sharing of techniques, capacity, observations and plans. The Indian Ocean has many littoral states bordering it, and has great spatial, temporal and geographic complexity and spread, almost too much to be treated as one regional IO-GOOS organization. Members might consider a federation of regions right from the start [along the lines of GOOS-Africa, SEA-GOOS, and WA-GOOS].

A core group of interested potential members have discussed the general guidelines for IO-GOOS development in 2001. The meeting, hosted by the National Institute of Oceanography and the Department of Ocean Development India, examined the current proposal and ways to move forward. To lead the process forward the Principals agreed to establish the Indian Ocean GOOS Development Committee [IOGOOS-DC]. Dr. K. Radhakrishnan, Director of the Indian National Centre for Ocean Information Services [INCOIS] at Hyderabad, was identified to serve as Chairman of the DC and provide the initial secretariat at INCOIS until such time as the IOGOOS is officially sanctioned by governments. Mr Rondolph Payet [Seychelles Fishing Authority] was identified to serve as Vice-Chairman. This secretariat will be listed by the GOOS Project Office as the contact point for matters pertaining to the Indian Ocean GOOS development process. The immediate tasks for the DC, as identified by the group, include finalizing the Indian Ocean Observing Strategy, and drafting an MOU to consolidate membership and basic goals. The Meeting Statement is appended. An expert group under the leadership of Dr. Ehrlich Desa, Director, NIO, India was requested to finalise the Indian Ocean Observing Strategy.

The IO-GOOS goal will be to coordinate the various elements of an observing system for the whole Indian Ocean, and to develop and implement pilot projects that may be basin scale or more regional in scope. Some of these projects will have sponsorship from UN agencies such as IOC, WMO, FAO, UNEP and others. The planning of the projects would normally occur within scientific and technical committees established for this purpose by the Indian Ocean body in cooperation with the global science project committees of bodies such as CLIVAR, WOCE, GLOBEC, GODAE, ARGO, HAB, OOPC and COOP. Personnel from potential IO-GOOS institutions are often members of such committees, and are aware that relationships with such projects would be to the mutual benefit of all.

The IO-GOOS design should reflect the interests of its individual members but also serve the common good. IO-GOOS should develop projects that are of interest to research and/or pre-operational services in countries from within the region. All the projects should reflect the principles associated with GOOS and have regional and global application. These may be related to UN sponsored projects; some may be more coastal or practical than others. By linking into GOOS they will benefit from the experience of other regional GOOS organizations and, also acquire access to the data and products available in the GOOS system. For example, regional coastal projects should benefit from the availability of boundary condition data from the basin scale approach. Regional members may want to organize projects that are solely regional in nature, for example the Mediterranean Forecasting Project within EuroGOOS. The membership of such sub-regional groups will be appropriate to the task.

- **Sector Responsibility Approach**

It is envisioned that certain IO-GOOS institutions will take responsibility for various sectors of observing systems, and such examples of competent institutions within IO-GOOS countries abound. In such cases, the observing systems will reflect the interests of an individual institution's mandate and charter. In taking on sector responsibility, however, the institution assumes a responsibility to the other participants to provide them the data and cooperate with them to the maximum extent. Such cases present opportunities and there is a clear need for identification of national, regional and global responsibilities which may be assumed by such institutions.

The sector approach should enhance the ability of an IO-GOOS institution to call on other institutions in the sector to join in the project. The institution should seek to enlist the support of fishing fleets, merchant vessels, weather bureaus, various users of products and scientists interested in using ocean data. Such local networking should result in cost-savings in the deployment and servicing of instruments and buoys, calibration of equipment, data management and distribution, communications and so on. Managers of marine facilities (managers of ports, fish farms, offshore oil rigs, ships and others) should be encouraged to participate by collecting and providing information useful in improving forecasts that will benefit them.

By managing a sector, an IO-GOOS institution may be better suited to apply the data and information to their region. Having responsibility for the sector and being located in the sector will enable them to tailor the design to meet local needs. This approach may also facilitate increased local support and funding for the activity as it becomes more relevant to the needs of the local area. National agencies will be better able to justify their contribution to the project by showing how it meets their own objectives and needs. In taking responsibility for a sector the IO-GOOS institution becomes responsible to the other participants in IO-GOOS and also to the global GOOS community.

As IO-GOOS develops it will solicit support for projects from outside donors. However, it first must present a serious planning effort and interest in delivering data, information and services, so as to attract donor support.

- **Project Selection**

Projects will be selected after full review by all IO-GOOS members and affiliates, and formally designated as IO-GOOS projects or activities thereafter. The decision can be made through meetings or email but should in any case reflect a consensus. All IO-GOOS projects will have to provide regional benefit.

Although it will be useful to develop projects in full concert with IO-GOOS, this cannot be mandatory, since occasionally projects will be developed elsewhere and may be transported into the region. This will be acceptable if it is deemed by

IO-GOOS to be beneficial to the region and is eventually approved and endorsed by IO-GOOS.

Projects will need to meet all criteria required by GOOS as determined by policies established by GOOS executive bodies. Projects may address coastal-ocean or open-ocean GOOS and GOOS capacity building requirements. In the area of capacity building, projects may be conducted within one country but may have long-term benefit for the entire region. Maximum effort should be made to provide access for the widest group of participants in such activities. Such benefits should be demonstrated to the IO-GOOS membership when seeking IO-GOOS designation for a project.

Project management and execution will always be at the discretion of the initiators but they should be encouraged to be as open as possible to other interested parties.

- **Capacity Building**

The purpose of capacity building is to make possible the continued involvement of nations in GOOS. Capacity building includes education and training; the building of appropriate institutional support structures; the creation of networks; infrastructure elements (e.g., platforms, sensors, data and modeling centers); and providing access to communication networks for data telemetry and dissemination (e.g., the Internet, downloading and visualizing satellite data). Capacity building is an integral component of GOOS activities including the design of the global network and pilot projects. A general education element with the aim of increasing public awareness of GOOS and the anticipated social benefits is an integral component.

Except for India and Australia, there are few oceanographic institutions able to provide the necessary ‘home’ for the development of expertise. IO-GOOS intends to provide a common mission to those countries bordering the Indian Ocean, so that individual nations can join international efforts to better monitor and analyze the surrounding oceans. From this concept of a greater partnership for the study of shared resources, it is expected that national governments will see the value of funding marine environmental research in an operational context.

Where infrastructure does not exist, strategies should be implemented to meet the following needs of nations:

- Develop and maintain a minimum scientific capability to support and participate in GOOS-related activities, through regional application centers
- Raise understanding of the value of in situ and space-based observations of the ocean to solving socio-economic problems, through educating

public and politicians on the benefits to be obtained from investing in developing, maintaining, and utilizing ocean observation systems.

- Collection of ocean data, including satellite measurements and in situ measurements necessary for their calibration, validation, and augmentation. (Special efforts should be made to create and sustain baseline networks in the coastal waters and EEZ of high quality surface-based stations or sections in a wide range of climates).

- Raise the ability of countries to contribute to and benefit from global observing systems. A long-term investment in facilities for receiving, processing, and interpreting data from ocean and space-based sources is needed. This must be accompanied by training in the use of such facilities and in the provision of services and products; e.g. seasonal predictions of drought, severe storm warnings, sea level rise, coastal zone and fisheries management, pollution and harmful algal blooms, coral reef disturbance and recovery etc.

An immediate capacity building need in the Indian Ocean is to carry out assessments and inventories of existing infrastructure, such as already done for marine meteorology by WIOMAP. This will enable GOOS planners to utilize and build onto local capabilities. Also, it is critical to establish GOOS planning processes in the countries surrounding the Indian Ocean by establishing GOOS National Coordinating Committees. This will enable countries to more fully participate in international forums planning GOOS such as the IOC, WMO and others, and to more realistically evaluate their own requirements and set out objectives. The general criteria of such a committee is:

i. To formulate an overarching framework for the development of a scientific program specific to IO-GOOS, that includes monitoring, data and modeling, and application to weather prediction and marine resource management, and capacity building;
ii. Consider user needs and specify the marine data and products required to satisfy those needs;
iii. Identify and work to improve existing national capabilities, including human skills and available technology;
iv. Identify gaps in those capabilities, including inadequacies in present observing and data management systems, and work to correct them, focusing (a) on training and practical assistance related to meeting users' needs in the coastal zone and elsewhere, and (b) on formulating plans to fill gaps;

v. Pay special attention to exploiting the opportunities offered by the increasing number and variety of observations of the coastal zone and open ocean from space satellites;

vi. Promote communication between marine scientists and coastal managers and other potential users of GOOS data and information through the development of national, regional and global electronic networking;

vii. Promote the design and implementation of regionally coordinated strategies for data acquisition, integration, synthesis and dissemination of products to improve coastal zone assessment, and the prediction of environmental change;

viii. Develop regional pilot projects to demonstrate the usefulness of the GOOS system, and encourage participation in ongoing GOOS pilot projects;

ix. Evaluate costs and benefits as the basis for persuading governments, donor agencies and the private sector to support a long-term ocean data acquisition program and associated infrastructure.

x. Promote GOOS development and expansion through appropriate communication.

As scientists launch projects such as GODAE, ARGO and other observing systems in the Indian Ocean they should be consciously considering the capacity building opportunities coupled with the contributions that developing countries can make. A small investment in training and education in the Indian Ocean region can result in a reduction in the cost of conducting research and sustained observations. The IOC through its Perth Office will seek to assist in this process by making the scientific planning groups aware of such opportunities and working to establish these activities. EuroGOOS in its early stages devoted substantial resources to inventorying and social/economic benefits of GOOS for the purpose of convincing governments to support GOOS. In the Indian Ocean a similar effort must be mounted.

The IOC has already initiated a number of capacity building activities in eastern Africa, including the WIOMAP concept and ICAM conference. These have yet to transferred into projects. GCRMN and ODINAFRICA are heavily weighted towards capacity building. The central and eastern Indian Ocean countries are in need of similar capacity building with respect to awareness and inventorying of capabilities and needs, in conjunction with SEA-GOOS. It should be anticipated that coastal GOOS would be of major interest to these countries based on the conclusion of the regional workshop held in India during 1997. This work needs to be expanded to target more of the region and to build on the preliminary results achieved in 1997. The solution is not in one-time workshops but in developing a process for sustained capacity building in concert with development of observation systems in the region.

- **Funding**

Most Indian Ocean research institutes derive their funding from national agencies. The members will be required to provide the funding needed to sustain IO-GOOS projects. For that reason, it will be desirable to engage entities that already have or can help with the funding required. A successful initiation of activities might result in additional supplemental resources from funding agencies that have the charter to assist in areas of climate change, disaster mitigation, environmental stewardship, etc.

In some cases certain national agencies may have responsibility for carrying out certain types of ocean monitoring, observing and data management. These are sometimes related to military, meteorological services, sea-rescue, fisheries management or other activities. It would therefore be beneficial for these institutions and agencies to be part of the IO-GOOS founding members.

There will be no financial obligation to maintain a secretariat or staff to manage the organization. Members will fund their own costs of attending meetings and contribute in-kind to support meetings. The organization will operate through a rotating secretariat supported by a host agency. Rotation will occur when the members decide it is appropriate and when a new host agency volunteers the support required. Most communications will be by e-mail.

- **Membership**

The organization will address all aspects of GOOS, and membership would therefore include marine institutes and agencies from both inside and outside the region having a shared interest in participating in sustained ocean and coastal observing of the Indian Ocean. **Essentially the price of membership is some real contribution to any area of the end-to-end system, from instrument deployment to product development.** Countries and agencies, within the region are free to contribute or withhold any observations they chose; however, withheld observations would not be considered part of IO-GOOS or GOOS as per IOC and WMO data policies. Countries outside the region, who wish to participate in an IO-GOOS form, necessarily need to exchange data with members of the region.

A unique aspect of IO-GOOS should be that it invites and includes as members of the organization, the chair or representative of the major science planning committees involved in the Indian Ocean. These would include WOCE, OOPC, CLIVAR, GLOBEC, WCRP, GCRMN, COOP and others. The important aspect is that since GOOS cooperates and builds on the scientific expertise of these committees (that have successfully planned sustained observations in the Indian Ocean), their inclusion would offer the benefit of their experiences in optimum planning and execution of GOOS activities in the region.

Each institution or committee would designate one official contact, who will be responsible for coordinating IO-GOOS activities. Countries with more than one interested institution would be encouraged to establish a national coordinating mechanism for IO-GOOS following the guidelines of IOC (see IOC's GOOS web page for details). The IO-GOOS would always be free to decide on a different approach for organization management.

- **National Sovereignty**

There is no aspect of IO-GOOS that minimizes or exempts any member from the requirements stated in the Convention on the Law of the Sea. All rights and protections afforded by the Convention will be maintained by all members and all obligations imposed by the Convention must be adhered to. IO-GOOS activities must conform to the Convention on the Law of the Sea and, when necessary, be approved by national governments.

- **Decisions**

Decisions will be by consensus.

- **Chairperson**

A chairperson, who will be designated to serve a term of two years, will preside over organizational meetings and most technical meetings. Technical meetings of IO-GOOS may designate a meeting chairperson in special cases based on prior consultations with the chairperson. In the event the chairperson cannot attend a meeting, a new chairperson only for that meeting will be determined by consensus of all the members present. If a chairperson resigns, a new chairperson will be determined by consensus of all the members.

Conclusion

Organizational development of an Indian Ocean observing system should be driven by the science and operational requirements of the region. We are at an early stage of developing an organizational framework because the needs for the Indian Ocean are still in the state of being defined.

It is recommended that soon after the Conference in Mauritius in early November 2002, as the process of planning observing systems firms and refines, that various member countries take up awareness programmes in their respective countries. The IOC Perth Regional Programme Office is prepared to assist in this process, which should include all the potential members identified in the above section.

INDIAN OCEAN PRINCIPALS' MEETING
- a High Level Consultation

New Delhi, November 8-9, 2001

MEETING STATEMENT

The world has become aware of the fragility of its living environment and its sensitivity to climatic change, natural disaster and human impact. Until now we have been unwilling spectators to the changes to our oceans and coastal seas. However, new tools are now available which give us an unprecedented ability to detect these changes and use observations to make informed decisions that save lives and protect our living habitats and resources. These tools include sensors on satellites, automated instruments that probe the depths of the ocean, powerful computers that enable the ocean state to be described and forecast and the electronic distribution of data and information worldwide. This makes possible a global coordination of ocean and coastal observing systems and the formation of alliances between nations to focus effort on the most pressing regional environmental dangers.

Recognising that the lives of at least 1.5 Billion people are profoundly influenced by the Indian Ocean, a meeting was convened at the India Habitat Centre in New Delhi, India on November 8-9, 2001, to take a proactive role in defining major initiatives to improve their quality of life. Principal representatives from 11 agencies attended. The focus of the meeting was the Global Ocean Observing System [GOOS] and its emphasis was on an Indian Ocean Regional Alliance [IOGOOS].

The Intergovernmental Oceanographic Commission's Office in Perth, Australia was the sponsor with logistical support from the National Institute of Oceanography in Goa, along with the Department of Ocean Development, Government of India.

The Principals recognized that problems of common concern of the Indian Ocean region could be addressed effectively through an umbrella organization that would take initiatives to encourage the development of appropriate regional and sub-regional ocean and coastal observing systems and services. These initiatives would link, where appropriate, with other GOOS initiatives including global GOOS. The organization would seek to ensure adherence to the GOOS principles and regional strategy guidelines. It would encourage standardization of observing techniques, the exchange of data and data management, cooperation in modeling and the sharing of responsibilities for observing platforms and communications.

A priority goal would be to create a system where all participants could contribute and utilize the data and products to their best advantage. Raising national capacity and promoting concrete mutual assistance initiatives would be a central focus of IOGOOS.

To lead the process forward the Principals agreed to establish the Indian Ocean GOOS Development Committee [IOGOOS-DC]. Dr K Radhakrishnan, Director of the Indian National Centre for Ocean Information Services [INCOIS] at Hyderabad, will serve as Chairman of the DC and provide a secretariat until such time as the IOGOOS is officially sanctioned by governments. Mr Rondolph Payet [Seychelles Fishing Authority] will serve as Vice-Chairman.

The initial Secretariat will be located at INCOIS. This secretariat will be listed by the GOOS Project Office as the contact point for matters pertaining to the Indian Ocean GOOS development process.

The immediate tasks of the DC include finalizing the Indian Ocean Observing Strategy, and drafting an MOU to consolidate membership and basic goals. It would also coordinate and be a communicating mechanism for the region to plan conferences, meetings and workshops that support development of IOGOOS. The DC will also further strengthen various bilateral S&T agreements existing among Indian Ocean Rim countries.

The Principals agreed to further IOGOOS objectives and to broaden the initiative in their respective countries. This will include encouraging the formation of National GOOS Coordinating Committees. The Principals will be the leaders of the initiative and will be the members of the Development Committee.

The creation of IOGOOS is a major milestone towards the access and application of oceanic knowledge to benefit all people of the Indian Ocean region.

The signatories to this Statement unanimously agree to establish the IOGOOS – Development Committee.

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