First Conference of the Indian Ocean Global Ocean Observing System

International Conference Centre, Grand Bay, Mauritius

2–9 November 2002

ACKNOWLEDGEMENT

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Climate Variability and Prediction Program
Department of Ocean Development (India)
Intergovernmental Oceanographic Commission (UNESCO)
Land-Ocean Interaction in the Coastal Zone (ICSU)
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First Conference of the Indian Ocean Global Ocean Observing System
International Conference Centre, Grand Bay, Mauritius
2–9 November 2002

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1. OPENING

Chair: K. Radhakrishnan
Rapporteur: Ray C. Griffiths

The Chairman of the Mauritius Oceanography Institute (MOI), Mr. Harry Ganoo, opened the Conference. He welcomed the participants to Mauritius in his own name and in that of the Director of the MOI, Dr Ranadhir Mukhopadhyay. Mr. Ganoo's statement is given in Annex 1a. Mr. Ganoo then invited the Executive Secretary IOC, Dr. Patricio Bernal, to take the floor.

Dr. Bernal expressed his appreciation to the Mauritian authorities for their kindness in hosting this important conference, and stressed the high appropriateness of the venue for the development of the proposed Global Ocean Observing System (GOOS) for the Indian Ocean. Dr. Bernal's statement is given in Annex 1b.

The Secretary of the Department of Ocean Development, India, Dr. Harsh K. Gupta, also thanked the Mauritian authorities for their kind invitation, and stressed the interest of the Department of Ocean Development (DOD) of India in the development of an Indian Ocean Observing System, following a long collaboration with Mauritius. Dr. Gupta's statement is given in Annex 1c.

The Hon. Mr. Rajesh Bhagwan, Minister for Environment, of Mauritius expressed the honor and privilege felt by his country in hosting this important Conference and in participating in the development of IOGOOS, which would be of great benefit to Mauritius. Mr. Baghwan's statement is given in Annex 1d.

The Chairman of the IOGOOS Development Committee (IOGOOS–DC), Dr. K. Radhakrishnan, proposed a vote of thanks to the Government of Mauritius, to the Intergovernmental Oceanographic Commission (IOC, of UNESCO) and to various persons who had made a particular contribution to the preparations for and organization of the Conference. Dr. K. Radhakrishnan's statement is given in Annex 1e.

The Program of the Conference is given in Annex 2, and the List of Participants, in Annex 3.

2. CONFERENCE STRUCTURE AND OBJECTIVES

The Ocean and Climate Workshop was charged with: consolidating and extending the regional networking that was started at the Workshop on Sustainable Observations for Climate in the Indian Ocean (SOCIO), Perth (November 2000) and at the Argo Workshop in Hyderabad (July 2001); working with the Coastal Ocean Observing Workshop to identify actions required to develop an Implementation Plan for the Indian Ocean Global Ocean Observing System (IOGOOS), building on the SOCIO Workshop, meetings of the Climate Variability (CLIVAR) Asian/Australian Monsoon Panel, and the Global Ocean Data Acquisition Experiment (GODAE) Science Team; and identifying the potential regional users' requirements for operational products derived from IOGOOS.

The Coastal Ocean Observing Workshop was charged with: establishing working relationships between the IOGOOS, Land-Ocean Interactions in the Coastal Zone (LOICZ, of ICSU) and relevant regional bodies (e.g., regional seas conventions, regional fishery bodies, large marine ecosystem programs); initiating a process that will lead to the establishment of a regional network (or networks) of coastal research laboratories and to the development of a Coastal Observing Network for the Near Shore (CONNS) for the design and implementation of the coastal component of IOGOOS; identifying phenomena of interest that are high priorities in the region (e.g., the coastal zones of the Arabian Sea, the Bay of Bengal and the Mascarenes Plateau) and that require sustained observations on a regional scale; formulating proof-of-concept pilot projects.

The Data Management Workshop was charged with: presenting information on data management in Africa (ODINAFRICA); and laying the basis of a plan for data management in the Indian Ocean region.

The Satellite Applications Workshop was charged with: providing examples of satellite applications in the Indian Ocean region; planning an expanded use of satellites for Indian Ocean observations relevant to IOGOOS; and improving collaboration and relevant capacity-building in the IOGOOS member countries.

The Round Table on International Scientific and Technical Collaboration was charged with: providing a forum for discussing areas of potential collaboration between regional and international institutions; identifying Indian Ocean regional facilities, data bases, and approaches to environmental characterization (such as unique environmental data sets, data-assimilation efforts, model-enhancement initiatives, coastal dynamics, and unique sensor systems or platforms); and present international scientific and technical collaboration funding programs that promote advances in science and technology in the region.

The Conference also provided the occasion for the formal signing of the Memorandum of Understanding on the creation of the Regional Alliance for the Indian Ocean Global Ocean Observing System (IOGOOS) and for the first meeting of the Alliance, at which its Officers will be elected. The coordination of GOOS Regional Alliances was also discussed.

3. CONFERENCE STATEMENT

The First Conference of the Indian Ocean Global Ocean Observing System (IOGOOS), in Mauritius, 4–9 November 2002:

Being constantly aware of their living environment and its sensitivity to climate change, natural disaster, and human impact, the Indian Ocean countries have decided to mobilize their resources to safeguard and manage their oceans and coastal waters through a permanent ocean observing system, the Indian Ocean Global Ocean Observing System (IOGOOS).

Nineteen organizations of 10 Indian Ocean countries signed a Memorandum of Understanding to create and actively participate in a Regional Alliance for IOGOOS, signed on 5 November 2002 during the First Conference of the Indian Ocean Global Ocean Observing System, in Mauritius, 4-9 November 2002.

This Memorandum of Understanding is one of the strongest instruments of cooperation and collaboration in the context of the oceanographic development of the region.

The Government of Mauritius, through its Mauritius Oceanography Institute, facilitated this landmark Conference, with sponsorship from eleven international and national agencies and programs: Intergovernmental Oceanographic Commission, World Meteorological Organization, Department of Ocean Development of India, US Office of Naval Research, US National Oceanic and Atmospheric Administration, US National Science Foundation, Mauritius Oceanography Institute, Climate Variability and Prediction Program, Australian Commonwealth Scientific and Industrial Research Organization, Land-Ocean Interaction in the Coastal Zone, Météo France.

The oceans may be viewed as keeping countries apart, but GOOS may be viewed as bringing them together. International conventions, such as the UN Framework Convention on Climate Change and the Convention on Biodiversity, and the economic challenges and social commitments have mandated countries to implement ocean observing systems.

IOGOOS is intended to elevate the Indian Ocean from one of the least studied to one of the most studied of the world's major oceans, with a real emphasis on the link between societal and scientific issues.

The 1.5 billion people of the Indian Ocean rim can now look forward to an increased ability to make use of the ocean observations and information produced by GOOS to improve the management of their marine environment and to use the ocean's resources sustainably.

IOGOOS will minimize the disconnect between procedures and requirements in the observation of the Indian Ocean, and enable the community to derive benefits from baseline data, routine and timely maps of ocean properties, and useful forecasts on all relevant time-scales. This will enable the detection of climate change in the marine environment with the least possible lag between changes and their detection.

The Conference proposed a number of actions and programs to give effect to the IOGOOS vision and to meet its objectives.

The basin-wide structure of temperature, salinity, and currents will be monitored by combining routine satellite data with pilot in situ measurements by Argo floats, moored buoys, XBTs, and other instruments.

A new data-management structure will disseminate integrated data products, including ocean analyses and climate predictions, to regional users, not least farmers and fishermen.

In the coastal zone, increased and coordinated study and monitoring of coastal erosion, habitat and biodiversity, and fisheries will be given priority, with the aim of forecasting change and of providing the best possible data products to the national authorities, managers and scientific communities.

The significance of the Conference lies in its explicit statement of commitment of the participating countries, agencies and institutions, and of interested nongovernmental organizations, to the generation of oceanic knowledge, data, and information and their application to the ocean- and climate-change problems of the Indian Ocean, and to the free and open access to such knowledge, data, and information, for the benefit of all the people of the Indian Ocean region and beyond.

Through the Conference, the Intergovernmental Oceanographic Commission (of UNESCO) and its UN and regional partners are now one step closer to establishing a fully operational Global Ocean Observing System in the Indian Ocean with the collaboration of the countries of the Indian Ocean region.

4. OVERVIEW PRESENTATIONS

Co-Chairs: Harsh K Gupta, G. Meyers
Rapporteur: Ray C. Griffiths

Six papers were presented. These and other invited presentations, and/or abstracts thereof, are available on the IOGOOS website: http://www.ns2.incois.gov.in/iogoos.

4.1 *Regional Interests in Ocean, Climate and Coastal Ocean-Observing Systems*

Satish Shetye presented this topic, which was co-authored by K. Radhakrishnan.

The presentation reviewed the wide variety of interests in ocean-observing systems from a regional perspective, including coastal ecosystems as defined by the GOOS Coastal Ocean Observations Panel. It outlined the probable causes and the climatic and oceanographic implications of the Indian Ocean's geographical exclusion from the north and south polar regions and the existence of the Indonesian (Indo-Pacific) Throughflow, which enhances the transport of the South Equatorial Current south of about 10°S. These implications are expressed principally in the form of:

- The strong southwest monsoon (June–September) and the weaker northeast monsoon (November–February) in the northern Indian Ocean

- The eastward-flowing Wyrtki Jet during the transition between the two monsoons, in May and in October
- The unique boundary currents (the East African Coastal, the Mozambique and the Agulhas Currents (from north to south) on the western side and the Leeuwin Current on the eastern side, off western Australia, and, during the southwest monsoon, strong seasonal boundary currents, such as the Somali Current
- The ventilation of the Indian Ocean basin by the subduction of water in the southern Indian Ocean and then northward flow at depth, because the subtropical convergence zone typically found in other major-ocean basins does not exist here
- Sea-surface temperature (SST) anomalies, mainly due to the combined effect of oceanic circulation and mixed-layer dynamics, and air–sea fluxes (the northern Indian Ocean receives a net heat influx across the air–sea interface)
- Tropical storms, which are most prominent in a zonal band centered approximately on 10°S, in the Bay of Bengal, and in the eastern Arabian Sea; the preferred period of cyclogenesis is December–March, with a maximum in January, in the southern part and, in the northern part, the primary maximum is in November, with a secondary maximum in May
- Meteorological depressions that migrate west-northwestward across the Bay of Bengal bringing rainfall to the Indian subcontinent
- Sea-level increase, seasonally and locally as a result of storm surges, and probably in the long term as a result of global warming
- The injection of the highly saline Red Sea Water and the Persian Gulf Water into the Arabian Sea at subsurface levels, which has a strong effect on the Indian Ocean's density structure
- The high precipitation over the northeastern Indian Ocean, which makes the surface waters of the Bay of Bengal and the Andaman Sea the least saline, but also strongly affects the density structure
- The formation of an intense oxygen-minimum layer, due mainly to the above-mentioned subduction and the high productivity of the Arabian Sea.

The eleven features are proposed as legitimate objects of long-term observation within an Indian Ocean ocean-observing system.

In particular, SST anomalies can provide advance warning of anomalous climatic phenomena, such as the El Niño and Southern Oscillation, the tropospheric Quasi-Biennial Oscillation, intraseasonal oscillations in the northern Indian Ocean, East African rainfall anomalies, southern Australian rainfall, the long-term trend in the SST itself, and the recently discovered Indian Ocean Dipole (IOD) which appears to form a coupled ocean–atmosphere system, offering the promise of prediction of related seasonal climatic anomalies.

Besides the large-scale processes described above, the coastal zone is subject to the impact of tides, local winds, river runoff, etc., differing from place to place, so that an observing system will need to take into account the differences in demands on the system from place to place; this will include keeping track of ecological and biogeochemical processes, as well as the physical processes, especially in the southern and central parts of the west coast of India which support a large fishing industry.

K. Radhakrishnan briefly addressed the Indian Ocean as an entity from the political, economic, social-cultural, environmental, scientific, technical, institutional, and other standpoints.

4.2 *Status of the Ocean and Climate Observing System*

Gary Meyers presented this topic, which was co-authored by Peter Hacker and Mark Jury.

The presentation provided an overview of the socio-economic and scientific rationale, present status and steps toward implementation of a regional ocean-observing system in the Indian Ocean.

The Indian Ocean is poorly monitored in comparison to the Pacific. The ENSO observing system provides a vision of what is possible for the Indian Ocean in the future. In principle, we seek a system using many different types of instruments, and integration of the data streams by the methods of ocean-state estimation.

The societal issues that can be addressed with the help of data products span time-scales from days to seasons to decades. Many of the impacts (e.g., storm-surges, floods) cluster in the shorter time-scales and are generated primarily by the upper ocean. They sometimes have serious economic consequences and/or pose a threat to the well-being of large populations and often require continuous, near-real-time data availability (e.g., for marine forecasts, search and rescue). At the longer time-scales, management of agriculture, land-use change, water resources and other issues related to climate variability and change are important.

The science issues also span a broad range of time-scales, and specific oceanic phenomena can be associated with the societal issues. Many of the faster time-scales are associated with physics of the intra-seasonal oscillation or ISO (e.g., mixed-layer processes, diurnal cycle, skin/bulk sea temperature). The Asian/Australian Monsoon Panel has developed the hypothesis that the intra-seasonal oscillation is the building block of the monsoons and their inter-annual variability, and that the ocean plays an active role in the ISO. The ISO may be the physical phenomenon driving the Indian Ocean Dipole (IOD). Data are needed to test the hypothesis because a capability to predict the intra-seasonal time-scale events will have important societal consequences. Data are required for studies of the surface-layer heat budget at time-scales from ISO to IOD. At longer time-scales, the Indonesian Throughflow is critical to understanding the basin-scale heat budget. A better understanding of climate change in the southern Indian Ocean and of meridional overturning will depend on observations of the thermohaline properties.

The scientific and societal issues in the development of the Indian Ocean observing system can be keyed to seven important drivers: climate change (D1); decadal variation (D2); seasonal to inter-annual variability (D3); intra-seasonal oscillation (D4); synoptic ocean-state estimation (D5); other research (D6); marine surface conditions and numerical weather prediction (D7).

The present-day and future observing platforms may provide data to address these drivers. Remote sensing of sea level, sea-surface temperature, and color is essential for the Indian Ocean, and addresses the faster time-scales (D3 to D7). The ongoing in situ measurements address different drivers: drifters (D7, D4); tide gauges (D1 to D3); Ship of Opportunity Project XBT (D1 to D6). The continuation and enhancement of all of these measurements are strongly recommended, emphasizing the fact that, in the Indian Ocean in particular, remote sensing will play a key role. Ocean-state estimation is recognized as the cross-linking theme for integration and initial interpretation.

Building on the ongoing satellite and in situ measurements, the next major enhancement of the Indian Ocean observing system will be the extensive deployment of Argo floats.

A tropical mooring array is a further enhancement particularly required to observe the role of the ocean in ISO. Designing and reaching consensus on a mooring array is a major challenge. Without stretching the imagination, an integrated view of the observing system that can realistically be achieved within the next few years includes high-density and frequently repeated Ship-of-Opportunity Project XBT lines, 3–5 currentmeter and TRITON TAO moorings in the equatorial region, 12 surface moorings in the northern Indian Ocean, approximately 90 surface drifters and 144 Argo floats. The Indonesian Throughflow will be monitored for three years by the international INSTANT Program.

4.3 *The Role of the Indian Ocean in Asian/Australian/African Monsoons and Climate Predictability*

Peter Webster authored and presented this topic.

The presentation reviewed what is known about monsoon variability and its links to the Indian Ocean.

The analysis of the available data reveals some very important points: the monsoon is a coupled system which has great predictability, so that probabilistic forecasts on all time-scales are possible. Nevertheless, at this time there are insufficient data for initializing the model.

The coupled phenomenon of most concern is the weather, particularly its intra-seasonal and inter-annual variability, its regulation and its predictability.

The variability is reflected principally in the sea-surface temperature, the precipitation, and the surface wind field, which, shown quarterly and by year, demonstrate this variability, intra-seasonally and inter-annually. The annual cycle of convection and of the surface wind field are found to be related.

Monsoon regions are largest where precipitation exceeds evaporation, raising the question: where does the water come from? Since the monsoon phenomenon is intrinsically inter-hemispheric, the water is considered to come from the hemisphere in which winter is occurring. The monsoons are related strongly to the land–ocean contrasts (in temperature and precipitation, for example) in a zonal band across the Arabian Sea, southern India, and the Bay of Bengal; and in a meridional band from the Indian continent southward between approximately 80°E and 95°E.

The inter-annual time-scale of monsoon variability is mainly determined by the sea-surface/land-surface temperature variations in the Pacific and Indian Oceans.

The intra-seasonal time-scale of monsoon variability is manifested in "envelopes" or clusters of weather events of 20–40 days of droughts or floods. This time-scale may be the most important, but it is also the hardest to forecast.

Monsoon weather comprises depressions and tropical cyclones that lead to short-lived local flooding or drought, high winds and, consequently, increased coastal erosion.

The El Niño phenomenon changes the Indian Ocean sea-surface temperature, the sea-surface topography and the regions of maximum precipitation. The monsoon precipitation is, however, usually low during an El Niño. Over the long term, there is a correlation of about 0.6 between the monsoon and El Niño, although there are very long periods of no significant correlation. And there are quite marked differences in rainfall patterns from one "normal" year to another.

Sea-surface temperature in the Indian Ocean shows strong persistence, hence offers the possibility of useful predictability. Nevertheless, the question remains: are there other modes of predictability, and is there a basic building block that would be useful in designing an ocean-observing system? The fairly recent revelation of the Indian Ocean Dipole is a strong ocean–atmosphere coupled system that may be linked to the El Niño–Southern Oscillation and to monsoon vigor. It is strongly tied to the annual cycle and to climate variability, especially with respect to the equinoctial "short rains" in East Africa. It appears that the dipole can remain vigorous for decades then go "quiet".

Analysis of key parameters, such as sea-surface temperature and sea-surface height, show a number of features useful for weather prediction. In spring, SST in the western Indian Ocean is greater than in the eastern Indian Ocean; in summer, the opposite is true. In the zonal (latitudinal-band) mode, in East Africa, the El Niño coastal rainfall exceeds the La Niña rainfall. In the same mode, warm SST in the western Indian Ocean corresponds to low sea-surface height (SSH), and vice-versa.

The short-term, intra-seasonal variation is a predominant feature of the Indian Ocean; it has similar features to the inter-annual variability, but the 20–40 day variation is far larger on the intra-seasonal time-scale. The system's behavior on the intra-seasonal time-scale is robust in its effects and duration. It is not yet clear whether the observed variation is a product of an ocean–atmosphere coupling. It does, however, impose a distinct form of precipitation, distinct wet periods and distinct wet areas.

The temporal evolution of the monsoon intra-seasonal oscillation (MISO) is marked by active phases propagating northward in the Indian Ocean then southward across southern Asia. At present, the MISO is still absent from models, but 25-day forecasts are being produced based on six features of the MISO. This would allow the possibility of predicting the probability of occurrence of socially relevant climate-related impacts.

The heat budget of the northern Indian Ocean is characterized by net gain of heat across the sea surface from the atmosphere and by surface transport of surface water northward across the equator in the boreal winter, which warms the northern and cools the southern Indian Ocean. Heat loss from the northern hemisphere is by southward transport of warm surface water in the boreal summer, which warms the southern Indian Ocean. The overall heat storage capacity of the Indian Ocean is mainly determined by the mean sea-surface temperature in, and the thickness of, the mixed layer. It is therefore important to recall that the thickness is largely determined by the wind field, and to note that the Indian Ocean shows a warming trend of more than 1°C per century.

The inter-annual variation in the oceanic heat transport is large in the Indian Ocean. Strong inter-annual variation in the monsoon is related to strong winds, strong Ekman (wind-driven) transport, southward transport of water, and marked by a cool northern Indian Ocean; the opposite holds for weak monsoon inter-annual variation. The alternation shows a tendency to produce an anomalous monsoon of opposite sign (i.e., strong to weak or weak to strong), hence a marked biennality in the system.

The IOZM becomes established at times of maximum anomalous upwelling associated with anomalous strong or weak monsoon.

4.4 *The Integrated Design Plan of the Coastal Module of GOOS and its Implementation as Part of IOGOOS*

Tom Malone authored and presented this topic.

Introduction

The combined effects of climate and human alterations of the environment are especially pronounced in the coastal zone where people and ecosystem goods and services are most concentrated and inputs of energy and materials from land, sea and air converge. Simply put, these are the primary reasons for making the establishment of the coastal module of GOOS a high priority.

The phenomena of interest in coastal ecosystems include global warming and sea-level rise and changes in circulation, coastal flooding and erosion, public health risks, coastal eutrophication, habitat modification, harmful algal blooms, invasive species, loss of biodiversity, sustainable capture and aquaculture fisheries, and chemical contamination. Changes in these phenomena affect marine operations, public safety and health, the integrity of marine ecosystems, and the sustainability of the living marine resources they support.

In terms of human impacts, overfishing was not only the first major human perturbation of coastal ecosystem dynamics; it is also a primary driver of ecosystem degradation on a global scale in that it exacerbates the effects of nutrient pollution, contributes to habitat modification and loss of biodiversity, and increases the susceptibility of coastal ecosystems to invasive species, harmful algal blooms, and outbreaks of disease.

At the same time, many of the changes occurring in coastal ecosystems are related to large-scale, natural processes such as El Niño Southern Oscillation events, the Pacific Decadal Oscillation (PDO), and the North Atlantic Oscillation. It is believed by many that the regime shift observed in the Gulf of Alaska during the late 1970s is among the most dramatic examples of such an effect. The shift in catch from shrimp to gadids and flat fish coincided with a rapid warming of surface waters associated with the PDO. Such events underscore the argument for an adaptive approach to fisheries management that accounts for the effects of changes in the environment as well as fishing mortality.

Together, observations such as these make a compelling case for a more holistic, unified approach to resource management and environmental protection, especially in coastal ecosystems where habitat alterations, water pollution and problems associated with harmful algal blooms and invasive species are most severe. For these reasons, environmental scientists and managers are advocating a new, more integrated, approach that considers both environmental effects and the effects of human activities.

Linking science and management more effectively

Implementing an ecosystem-based strategy requires the capability to engage in adaptive management, a process that depends on our ability to routinely and rapidly detect changes in the environment and living marine resources and to provide timely predictions of changes in or the occurrence of the phenomena of interest. We do not have this capability today and this is an important reason for linking the coastal and ocean-climate modules of GOOS.

Effective management and sustainable use also depend on efficient/timely coupling of the processes by which new scientific knowledge is gained and the fruits of this knowledge are used for the public good. Today, there is an unacceptable disconnect between these processes.

A new approach is needed that enables adaptive management through routine, continuous and rapid provision of data and information over the broad spectrum of time–space scales required to link ecosystem scale changes to basin- and global-scale forcings. The “developed” world is on the cusp of a revolution that just might make such approaches feasible. The revolution is occurring on two related fronts: (1) advances in observing and modeling capabilities, and (2) the emergence of operational oceanography. The latter is the focus of this presentation.

The Global Ocean Observing System (GOOS)

An operational observing system for the marine environment is a new concept for oceanographers and marine ecologists, very few of whom have actually engaged in an "operational" observing system in which the provision of data and data-products is sustained and routine in forms and at rates that are specified by the users. Such a user-driven, end-to-end system requires a managed and efficient flow of data and information among three essential subsystems: (1) an analysis and modeling subsystem, the data requirements of which guide the development of (2) an integrated data communications and management subsystem for serving data of known quality in real-time or delayed mode as needed and (3) an observing subsystem for monitoring the required variables on specified time–space scales, precision and accuracy.

Under the oversight of the GOOS sponsors (IOC, UNEP, WMO, ICSU, FAO), the observing system is being organized in two related and convergent modules: (1) the global ocean module being developed by the Ocean Observations Panel for Climate and (2) the coastal module being developed by the Coastal Ocean Observations Panel. The former is primarily concerned with changes in and the effects of the ocean–climate system on physical processes and the global carbon budget. The latter is primarily concerned with the effects of climate and human activities on coastal ecosystems and socio-economic systems of coastal nations.

To achieve these goals, the GOOS movement is an attempt to more effectively link and enhance existing programs for more cost-effective use of existing knowledge, infrastructure and expertise; and more rapid detection and timely prediction of environmental changes and events in coastal marine and estuarine systems. It is an effort that, if successful, will not only increase the value of research, it will foster more effective linkages between science and the application of advances in science for the public good.

GOOS is intended to serve a function similar to that of the observing system for the World Weather Watch (WWW). Thus, the observing system is envisioned as a network of national, regional, and global systems that rapidly and systematically acquire and disseminate data and data products to serve the needs of many user groups, including government agencies, private enterprise, scientists, educators, NGOs and the public. Just as weather forecasts are not possible without sustained observations and operational models, adaptive, ecosystem-based management and environmental protection will not be possible without an operational observing system. In this model, scientific knowledge, technologies and research provide the means to design and develop GOOS in response to user needs. In this context, to the extent that the research enterprise attempts to become operational, the art of science will be compromised.

Design of the coastal module of GOOS

The “Integrated Design Plan for the Coastal Module of GOOS” has just been completed by the Coastal Ocean Observations Panel (COOP) and can be found at http://ioc.unesco.org/goos/COOP-4/coop4.htm.

The sponsors charged COOP to formulate design and implementation plans for an observing system that will provide the data and information required to achieve six goals: (1) improve the safety and efficiency of marine operations, (2) mitigate the effects of natural hazards on coastal communities and ecosystems more effectively, (3) improve predictions of climate changes and their effects on coastal communities and ecosystems, (4) minimize public health risks, (5) more effectively protect and restore healthy coastal marine ecosystems, and (6) sustain living marine resources. Clearly, this is a formidable task. However, although each of these goals has unique data requirements, all six have many data requirements in common. This is the basis for developing an integrated approach to detecting and predicting changes in coastal marine and estuarine systems.

The design plan for the coastal module must consider many factors. These include: the need to address a broad diversity of phenomena encompassed by the six goals; the fact that the phenomena of interest are globally ubiquitous and tend to be local expressions of larger-scale forcings; and ecosystem theory which posits that the phenomena of interest are related through a hierarchy of interactions that can be modeled. The design must also take into consideration certain important realities: priorities vary among nations and regions; many of the elements required to build the observing system are already in place; those elements of the observing system required to improve marine services and forecast natural hazards are most developed while those required for ecosystem-based environmental protection and management of living resources are least developed; and most nations do not have the capacity to contribute to and benefit from the observing system at this time. In addition, the design of the coastal module must take into consideration the importance of the regional scale that links global- and local-scale changes, i.e., most agreements and conventions that target environmental protection and resources are regional in scope and regional bodies provide the most effective venue for specifying user-group requirements for environmental data and information.

These considerations have important consequences in terms of the design of the coastal module: (1) the design must respect the fact that priorities vary among regions and should leave system design on the regional scale to stakeholders in the regions; (2) economies of scale can be achieved by establishing a global system that measures variables and manages data streams required by most regions; (3) the global coastal network will come into being through a combination of national, regional and global processes; (4) the system can be implemented by selectively linking existing elements and can be developed by enhancing and complementing these elements over time; and (5) high priority must be placed on capacity-building in developing countries, establishment of the data communications and management infrastructure, establishment of internationally accepted standards and protocols for measurements, data exchange, and data management; and on marine research to develop the sensors and models required to achieve those goals that require biological and chemical data.

Clearly, the coastal module must include both global- and regional-scale components. This can best be achieved through a global federation of regional systems in which the global network is established to measure and process a small set of common variables that are required by most, if not all, regional systems. The network provides economies of scale and improves the cost-effectiveness of regional observing systems by minimizing redundancy and optimizing data and information exchange; establishes reference and sentinel stations; and establishes international standards and protocols for measurements, data exchange and management.

GOOS Regional Alliances, guided by national and regional priorities, create Regional Application Centers for the provision of data/information products that are tailored to the requirements of user groups in the region and design and implement regional observing systems that enhance the global network by measuring more variables with greater time–space resolution, depending on national and regional priorities. In this way, regional observing systems both contribute to and benefit from the global network.

It must be emphasized that the global network will not, by itself, provide all of the data/information required to detect/predict changes in the phenomena of interest. There are categories of variables that are important globally, but the variables measured and the time–space scales of measurement change from region to region. These include variables in the categories of stock assessment; essential fish habitats, such as SAV, kelp beds, tidal wetlands and coral reefs; large organisms such as turtles, marine mammals, and seabirds; invasive species; harmful algae; and chemical contaminants. For these categories, decisions concerning exactly what to measure, the time–space scales of measurement, and the mix of observing techniques are best made by stakeholders in the regions affected. Thus, regional observing systems are critical building blocks of the coastal module of GOOS, especially for achieving the goals of sustaining and restoring healthy marine ecosystems and living marine resources.

It must also be emphasized that the data-management and communications subsystem is the “life-blood” of the observing system, and the development of an integrated data management and communications subsystem is arguably the highest priority for implementation. It must also be emphasized that observing and modeling are mutually dependent and together provide the means to estimate fields and fluxes that cannot be observed directly.

Under current conditions, data are often not exchanged freely among nations and, even when data are not proprietary, data management and analysis tend to be program-specific, and analyses that require multi-disciplinary data from many sources take too much time. The goal is to establish an integrated data-management subsystem that serves data in both real-time and delayed mode and allows users to exploit multiple data sets from many different sources through “one-stop-shopping.” The integrated plan is based on a hierarchical, distributed network of local-, regional- and global-scale data-management activities that build on, link and enhance existing data-management centers and programs.

Barriers to implementing the coastal module

The creation of a Joint Technical Commission for Oceanography and Marine Meteorology and initiatives such as the Argo and GODAE projects reflect the progress that is being made in the design and implementation of the global ocean module of GOOS. In contrast, although a high priority of the international community, progress in developing the coastal module has been slow. This is primarily a consequence of (1) the challenge of designing and implementing an internationally accepted coastal module to achieve the six goals in a diversity of complex coastal ecosystems; (2) the challenges of developing the regional and global partnerships needed to fund, implement, operate, and develop operational observing systems; (3) inefficient and ineffective data communications and management systems; and (4) the primitive state of our capacity to rapidly and routinely detect and predict changes that require measurements of biological and chemical variables.

Building the coastal module

The coastal module of GOOS will be built through phased implementation that is guided by two realities: (1) real-time measurements, data assimilation and modeling are more advanced for meteorological and physical applications than for ecological applications; and (2) developing countries in the southern hemisphere must be empowered to both benefit from and contribute to the observing system. In regard to (1), although some biological and chemical variables should be included from the beginning, initial investment will emphasize the measurement and analysis of physical variables. This places a high priority on the development of the new technologies and knowledge required to detect and predict changes in the biology and chemistry of coastal ecosystems. In regard to (2), investing in sustained capacity-building must be a high priority, especially in the southern hemisphere where the oceans (which account for about 60% of the global ocean) are poorly understood and monitored relative to oceans in the northern hemisphere.

The coastal module of GOOS and IOGOOS

IOGOOS has the potential of being a model for the development of a regional observing system in a region dominated by developing countries. Implementing the coastal module in the Indian Ocean will require partnering among regional bodies. These may include the SE Asia Center for Atmospheric and Marine Prediction; the Regional Cooperation in Scientific Information Exchange and the Oceanographic Data and Information Network of East Africa; fishery bodies such as the Indian Ocean Tuna Commission, Western Indian Ocean Tuna Organization, Regional Commission for Fisheries, and South West Indian Ocean Fishery Commission; Regional Seas Conventions such as the Nairobi Convention; Large Marine Ecosystem programs (LMEs) such as those planned for the Agulhas Current, Somali Coastal Current, Arabian Sea and Bay of Bengal; and the Global Coral Reef Monitoring Network and the Coral Reef Degradation in the Regional Indian Ocean program.

The formation of a GOOS Regional Alliance for IOGOOS should not only provide the most effective means of establishing regional priorities and user requirements, it should provide a venue or framework for establishing and maintaining the regional partnerships that will be needed to implement and develop the coastal module of IOGOOS. In addition, the development of IOGOOS should involve collaboration with GOOS–Africa and SEAGOOS.

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4.5 *Hyperspectral Imaging for Environmental Monitoring*

Following a brief introduction by Chris Butler, who expressed Walter McKeown's regret at being unable to attend the Conference, Merv Lynch, made the presentation on behalf of the author.

The presentation provided an overview of the GIFTS/IOMI satellite contribution to the Indian Ocean observing system. The NOAA–NASA–Navy Indian Ocean Meteorological Imager (IOMI) will be launched (as GIFTS) in early 2006, spend a year over the United States, then move (as IOMI) into geosynchronous orbit over the Indian Ocean region over 75°E longitude in 2007. For meteorology, high-resolution atmospheric soundings on a 4-km spatial scale and a 90-min temporal scale will provide enhanced atmospheric-structure information to national weather services, ensure improved performance of synoptic weather models, and should improve forecasts of typhoon and monsoon intensity changes. Since the high-resolution infrared spectrum discerns gases (CO and O_3) not normally detected by present geosynchronous satellites, wind vectors derived from feature-tracking techniques will allow the creation of wind profiles and wind shear on a 10-km spatial scale and these will be applicable to weather forecasts, pollution migration and aviation.

For oceanography, hyper-accurate (RMSE = 0.25°C), multi-channel radiometric sea-surface-temperature measurement (MCSST) is possible because the retrieval of atmospheric structure from an infrared spectrum requires accurate removal of background surface radiance. MCSST measurements made hourly with 4-km spatial resolution, combined with time-compositing techniques, will reveal Indian Ocean dynamics. Over the eastern Pacific and the western Atlantic Oceans, time-compositing is being used on GOES data to construct a daily thermal image of ocean patterns, using the warmest MCSST or strongest radiance in each pixel. Since clouds move much faster than ocean water, the compositing results in a mostly cloud-cleared image of each day's ocean thermal patterns. The forecaster can combine these dynamics with the simultaneous synoptic weather patterns to improve understanding of the role regional air–sea interactions plays in local weather.

Since IOMI can measure the spectral variation of the emissivity of surface materials in the 8–12 μm region, the application of “spectral emissivity” to a variety of geological, botanical and agricultural studies is possible. Also, since the mid-IR emissivity is due to molecular characteristics rather than reflection and since IOMI measures at high spectral resolution (2100 IR channels in two bands), the appearance and change of unique features in spectral emissivity may indicate changes in the properties of surface materials of interest.

During it’s planned 7-year lifespan, IOMI will thus be providing more detailed environmental information for the Indian Ocean region than will be available over the USA. How the IOGOOS community pioneers the applications of this free information will be of great interest to the world’s environmental scientists.

4.6 *Indian Ocean Observing Strategy*

Besides the overview presentations, Ehrlich Desa presented a proposed Strategy for the development of the Indian Ocean Global Ocean Observing System (IOGOOS). This strategy was developed from a draft by the IOC Perth Regional Programme Office; it is summarized here.

The Strategy first defines the importance of observing the oceans in general and the Indian Ocean in particular, the influence of oceanic processes on weather and climate, and our still limited ability to forecast weather and global climate change so as to pre-empt the disastrous effects of events such as cyclones and El Niño. Our ability to forecast weather, to sustainably use the marine resources, and maintain the ecosystem values of the marine environment is effectively dependent on rapid detection and timely prediction of the changes in ocean processes. Since oceanic processes in one part of the globe remotely influence changes in weather in other parts, there is a need to observe ocean parameters in a coordinated way through international cooperation.

The IOC Global Ocean Observing System (GOOS) is being developed in two related and convergent modules: (1) a global-ocean module concerned primarily with changes in the ocean–climate system and with improving marine services, especially hazard warnings; and (2) a coastal module concerned with fishery management, human activities and their impact, and the local/coastal effects of large-scale changes in the ocean–atmosphere coupling.

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 GOOS Regional Alliances should develop a hierarchical, distributed network of local, national, and regional mechanisms feeding eventually into a global framework, using common standards and protocols for quality control, access to and exchange of data, and archival.

The specific characteristics of IOGOOS are determined by the geophysical, oceanographic, and climatological characteristics of the Indian Ocean itself. In particular, and unlike the Pacific or the Atlantic Ocean, it has no access to the Arctic, so that, in its northern part, the sea-surface circulation reverses every half-year. The climate is therefore dominated by the monsoon system that drives the agrarian economy of most of the Indian Ocean countries.

The Strategy takes into acount regional factors. For example, regional marine science cooperation in the Indian Ocean has, in general, been difficult to initiate and sustain. 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 which hamper the sharing of information on the marine environment. Within individual countries, different agencies may have different objectives, and priorities and mechanisms that would allow cooperation are lacking.

The IOGOOS Strategy has the benefit of the experience of nine other GOOS Regional Alliances, although each is imprinted with its main regional characteristics and needs.

The IOGOOS Strategy has the benefit of IOC's long experience in supporting a wide range of projects and activities in the region over the years. Besides the International Indian Ocean Experiment (IIOE), there is the World Ocean Circulation Experiment (WOCE), JGOFS (Joint Global Ocean Flux Study), IODE (International Oceanographic Data and Information Exchange), ICAM (Integrated Coastal Area Management), GCRMN (Global Coral Reef Monitoring Network), and others. The IOC is moreover 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 Cooperative Investigation in the North and Central Western Indian Ocean (IOCINCWIO).

The needs of the African coastal countries for integrated coastal-area management were addressed by the IOC through the Pan-African Conference on Integrated Coastal Management (PASICOM) at Maputo in July 1998.

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, with the primary objective of developing GOOS in the Indian Ocean, the South Pacific, the Southern Ocean, and Australia.

The Strategy will take advantage of existing observing systems and facilities; for example:

- IOC Global Sea-Level Observing System (GLOSS)
- WMO–IOC Ship-of-Opportunity Program (SOOP)
- WMO–IOC Data Buoy Cooperation Panel (DBCP)
- WMO Voluntary Observing Ship (VOS) Network
- Global Coral Reef Monitoring Network (GCRMN)

It will also take advantage of some pilot projects, notably:

- Storm-Surge Warning System: a project for the northern part of the Indian Ocean, as a contribution to Coastal GOOS, is being developed by IOC and WMO
- The Western Indian Ocean Marine Applications Project (WIOMAP): a project to monitor the coastal impacts of severe weather events and to improve knowledge and marine prediction
- The Indian Ocean Moored Array Project (I-MAP) to monitor subsurface ocean conditions and surface fluxes around the western end of the Indian Ocean dipole.

Similarly, the Strategy will take advantage of some pre-operational projects:

- Argo: a project envisaged to establish a global array of 3000 floats by the year 2005; about 450 floats will be launched in the Indian Ocean
- Global Ocean Data Assimilation Experiment (GODAE): aimed at global ocean-state estimation, and at demonstrating the feasibility of operational oceanography
- Triton Array: two Japanese moored buoys in the eastern Indian Ocean to monitor the eastern end of the Indian Ocean dipole
- Indian Met-ocean buoys in the equatorial region of the Indian Ocean.

For data management, the Strategy will take advantage of the following projects that are part of the IOC's International Oceanographic Data and Information Exchange (IODE):

- IOC Regional Cooperation in Scientific Information Exchange in the Western Indian Ocean (RECOSCIX)
- IOC Oceanographic Data and Information Network in East Africa (ODINEA), which is now part of an Africa-wide initiative ODINAFRICA
- IOC Global Oceanographic Data Archaeology and Rescue (GODAR) Project.

Finally, the Strategy will be based on the following operational satellites providing oceanographic data for the Indian Ocean at present: ERS-1, ERS-2 (ESA); RADARSAT-1 (Canadia/USA); CBERS1 (China/Brazil); SPOT 1, SPOT 2 (France); IRS-1B, IRS-1C, IRS-1D, IRS-P3, IRS-P4 (India); MOS-1A, MOS-1B (Japan); TRMM (Japan/USA); KOMPSAT (Republic of Korea);

TIROS/NEXT (US NOAA); SeaWiFS (USA); LANDSAT 5, LANDSAT 7 (USA); QuikSCAT (USA); TERRA (USA); DMSP 5D-1, DMSP 5D-2, DMSP 5D-3 (USA); TOPEX/POSEIDON (USA/France); ROCSAT-1 (Taiwan); IKONOS-2 (Space Imaging).

The Strategy incorporates relevant capacity-building involving: education and training; the building of appropriate institutional support structures; the creation of networks; development of infrastructural elements (e.g., platforms, sensors, data and modeling centers); and provision of access to communication networks for data telemetry and dissemination (e.g., the Internet, downloading and visualizing satellite data). A general educational element aimed at increasing public awareness of GOOS and its expected social benefits is an important component of this IOGOOS capacity-building.

Where infrastructure does not exist, the Strategy is aimed at meeting the following needs of the Indian Ocean countries:

- Development and maintenance of a minimum scientific capability to support and participate in GOOS
- Raising understanding of the value of in situ and space-based observations of the ocean in solving socio-economic problems, through educating the public and politicians on the benefits to be obtained from investing in, developing, maintaining, and utilizing ocean-observation systems
- Collection of ocean data necessary for the calibration, validation, and enhancement of assimilative and predictive models
- Raising the ability of countries to contribute to and benefit from global observing systems, by long-term investment in facilities for receiving, processing, and interpreting data from ocean and space-based sources, accompanied by training in the use of such facilities and in the provision of services and products.

5. OCEAN DYNAMICS AND CLIMATE WORKSHOP

Chair: Gary Meyers
Rapporteurs: Peter Hacker, Ed Harrison

The sessions of this Workshop were held in parallel with those of the Coastal Ocean Observing Workshop, unless otherwise indicated (Joint Workshop Plenary Session, section 7, below).

The Chairman of the Ocean Dynamics and Climate Workshop, Gary Meyers, reminded the participants that the purpose of the Workshop was to take the next steps in planning implementation of a basin-wide, pilot observing system, building on the results of the Workshop on Sustained Observations for Climate in the Indian Ocean (SOCIO), held in Perth, Australia, in November 2000. The results of SOCIO (http://www.marine.csiro.au/conf/socio/socio.html) led to pilot moorings and Argo float deployments. Meyer called for a revision of plans for sustained pilot observations, with a critical eye on identifying what is feasible and what would have an impact. Feasibility is judged by the reality of getting the resources to put things in the water in the near term while sticking to the agreed research goals in the long term. Impact refers to the research and societal benefits that can be derived from sustained pilot observations. The Chairman also asked the participants to keep in mind another outcome of the SOCIO Workshop—ocean-state estimation is a cross-linking theme integrating the observations and making them available for many different kinds of applications.

The Workshop Chairman also recalled some significant findings outlined in the Conference overview papers summarized in the Overview Presentations section, above, covering recent progress in understanding the role of the Indian Ocean in regional climate variability and change, including advanced approaches to ocean-state estimation.

The intra-seasonal time-scale stands out in modeling and satellite-based observational studies as an exceptionally strong variability mode, often associated with important societal consequences, such as storm surges and floods. Peter Webster had identified the intra-seasonal time-scale as “the building block of the monsoons.” The Indian Ocean, however, shows persistence and predictability on a range of scales from the intra-seasonal to the inter-annual. A sound understanding of seasonal to inter-annual variations and predictability may not be achieved without good data and models on the intra-seasonal time-scale.

The circulation of the Indian Ocean is quite different from that of the Atlantic and Pacific Oceans, mainly because it has a closed boundary at low latitude to the north and an opening to the Pacific's warm equatorial waters to the east; this generates unusual currents (e.g., a three-dimensional monsoon circulation, the Indonesian Throughflow, and the Leeuwin Current) and unique heat transport and fluxes. A key conundrum is: How does the Indian Ocean get rid of the excess heat it gains through the sea surface? The answer to this question bears on the predictability of seasonal, inter-annual, decadal and longer-term climate variability and change. It also bears on understanding of the shorter time-scales and their important societal impacts (e.g., tropical cyclones, storm surges).

Four papers were presented on the three main ocean-monitoring systems: Argo floats; a basin-scale mooring array (for temperature, salinity and currents); and the SOOP XBT network.

Susan Wijffels presented a paper, coauthored by K. Radhakrishnan and Chris Reason, on the "Scientific Basis and Plans for an Argo Float Array."

Yukio Masumoto presented a paper, coauthored by V.S. Murty, on the "Scientific Basis and Plans for an Equatorial Mooring Array."

V.V. Gopalakrishna presented a paper on the "Scientific Basis and Results from the XBT Network."

Herman Ridderinkhof presented a paper on a "Long-term Mooring Array in the Mozambique Channel."

Five papers were presented on Indian Ocean research and monitoring, to set the scene for linking climate observations to regional and societal issues, such as coastal marine resources, pelagic fisheries, regional marine activity (e.g., weather, safety at sea, long-term nearshore moorings) and activity in the Global Climate Observing System (GCOS).

Paul Mason presented a paper, coauthored by William Westermeyer, on the "Global Climate Observing System."

Sok Appadu presented a paper, coauthored by Laban A. Ogallo (senior author), on the "GCOS Action Plan for Southern and Eastern Africa."

Gabriel Vecchi presented a paper, coauthored by Ed Harrison and S. Gadgil, on "Subseasonal Variability and Climate in the Indian Ocean."

Tony Lee presented a paper on the "Indian Ocean Structure and Climate from Satellite Data and Models."

Peter Hacker presented a paper, coauthored by P. Dutrieux, K. Radhakrishnan, E. Desa and S. Wijffels, on "Indian Ocean Climate Research Data Centers."

Three other papers were presented on special though relevant topics.

Neville Smith presented a paper on "Operational Oceanography."

Claire Périgaud presented a paper on "The Role of Salinity and Rainfall in Variability of the Indian Ocean."

Laurent Perron presented a paper on "Météo France: Regional Marine Activities in La Réunion Island."

Extended abstracts of the above-mentioned presentations are available at **ftp://www.marine.csiro.au/pub/meyers/** and on the IOGOOS website http://www.ns2.incois.gov.in

Following these presentations, the Workshop created two sessional Working Groups.

5.1 *Working Group 1 – Basin-scale Contributions to the Observing System*

Co-chairs: Mike McPhaden, Susan Wijffel
Rapporteurs: Peter Hacker, Ed Harrison

Working Group 1 was concerned with present and future availability of basin-scale observations and the need to develop an implementation strategy that builds on the plans developed at the SOCIO Workshop in Perth (November 2000). The Working Group was asked particularly to:

- Identify the next steps that will have an impact on research progress and deliver climate services
- Decide the mooring array required for the Indian Ocean and the strategy to implement the array in stages
- Determine the spatial and temporal priorities for Argo deployment, based on the scientific issues of the region, and develop specific Argo deployment plans (i.e., find ships that go where they are needed)
- Define the principles and guidelines for integrating the ocean, climate and coastal observing systems.

The Working Group's report is discussed below in section 5.3 (Working Group Reports) and section 7 (Joint Workshop Plenary Session).

5.2 *Working Group 2 – Regional-scale Contributions to the Observing System*

Co-chairs: K. Radhakrishnan, Gary Meyers
Rapporteurs: Neville Smith, Art Alexiou

Working Group 2 was concerned with the regional priorities, needs, and contributions to Indian Ocean GOOS, supplementing the needs identified at the SOCIO Workshop and bearing in mind that the proposed actions and projects should be of value to people in the region. The Working Group was asked particularly to answer the following questions:

- What available observations are most relevant to different regions, and why?
- What additional observations are needed and what can regional countries provide?
- What is the strategy to facilitate fusion of satellite data with in situ data?
- What analyses and data products will be useful for the Indian Ocean region as a whole, or for different sub-regions?
- What skills, capabilities and capacity does the region need to use the products effectively?
- What are the principles and guidelines for integrating the ocean, climate, and coastal observing systems in particular regions?
- How can awareness and the study of the socio-economic impact be improved?

The Working Group's report is discussed below in section 5.3 (Working Group Reports) and section 7 (Joint Workshop Plenary Session).

5.3 *Working Group Reports*

Reporters: Peter Hacker, Neville Smith

5.3.1 Working Group 1 on Basin-scale Contributions to the Observing System

The Working Group proposed three pilot projects: (1) to develop the deployment of Argo floats, from the present level of about 67 to 170 in 2003, and to 450 in 2005; (2) to develop Indian Ocean mooring arrays, especially in the equatorial zone, but also in the four zones of high sea-surface temperature anomalies (northern Bay of Bengal, off the southern coasts of Sumatra and Java, western Arabian Sea, and the southern Indian Ocean); (3) the implementation of a new Ship-of-Opportunity XBT Project, with emphasis on high-resolution, frequently repeated lines across the Indian Ocean. However, the other elements of the sustained integrated ocean-observing system for climate that have been identified as needed were not discussed, for lack of time.

The **Argo program** seeks to describe ocean temperature and salinity variability on seasonal and longer time-scales for space-scales of 1000 km and larger. The present strategy is to initiate coverage of as much of the basin as possible, even if at a reduced spatial resolution.

Regarding **mooring arrays**, India intends to maintain an array of about 40 surface moorings in waters north of 5°N, but details of the initial planned deployment were not made available. OOPC recommendations for sustained ocean air–sea reference-site moorings identify three Indian Ocean sites: the Arabian Sea, the Bay of Bengal, and the subduction region west of Australia toward mid-basin. The northernmost two of these three sites would clearly contribute to subseasonal-variability studies.

Several projects (see presentation by Matsumoto et al., mentioned above), in development or already funded, address various aspects of these issues: the French equatorial array near 73°E; the IMAP array, led by South Africa; an equatorial waveguide array to complete sampling of the waveguide and ISO propagation into the Bay of Bengal (USA and other countries); an ambitious array of 40 moorings north of 5°N, funded by the Department of Ocean Development (India), and for which, a mix of surface and subsurface moorings will be proposed.

Regarding the **Ship-of-Opportunity Project**, the advent of Argo and precision altimetry has changed the context within which the Project operates. Line-mode sampling (high-resolution and frequently repeated lines) is expected to promote synergy with Argo, satellite altimetry, and moored arrays; there is a special utility of such sampling in boundary regions and it has a unique role in heat and freshwater transport calculations.

5.3.2 Working Group 1 on Regional Contributions to the Observing System

The Working Group covered three main issues: exploitation of climate predictability; fishery applications; and ocean data and data products. The activity in each of these areas in the Indian Ocean is expected to operate on three levels: global; regional; and local

At the global level, international programs (e.g., CLIVAR, IOGOOS) will establish observing networks, and major analysis centres will prepare products and predictions covering global themes relevant to the Indian Ocean region, such as meteorology, oceanography, and climatology.

At the regional level, such global products generally do not have enough spatial detail for applications (e.g., agriculture, fisheries) and, consequently, downscaling by statistical and/or dynamical methods is required. Specific oceanic features may need to be enhanced in the products, which may require better ocean climatology and bathymetry.

At the local level, which was specifically addressed by the Conference's Coastal Ocean Observing Workshop, the regional concerns, such as management of the risk of climate variability and of change in the marine environment, fish production, and coastal erosion, will need to be addressed.

These two project proposals were discussed in detail in the Joint Plenary Workshop Session (section 7, below) of the Ocean Dynamics and Climate and the Coastal Ocean Observing Workshops.

6. COASTAL OCEAN OBSERVING WORKSHOP

Chair: Tom Malone
Rapporteur: Julie Hall

6.1 *Plenary Session: Invited Talks*

Tim McClanahan presented a paper on the "Impacts of Ocean Climate Variability on Coastal Marine Resources" by Mark Jury and himself.

John Gunn presented a paper on "Pelagic Fisheries Related to the Large-scale Physical Environment" by Francis Marsac and himself.

Neville Smith presented a paper on "Operational Ocean Analysis."

These presentations are available on the IOGOOS website: http://www.ns2.incois.gov.in

6.2 *Breakout Session I: Coastal Phenomena of Interest*

Using the recently completed “Integrated Design Plan for the Coastal Module of GOOS” as a guide (http://ioc.unesco.org/goos/COOP.htm), 60 representatives of the coastal research and coastal-zone management communities from 16 countries in the Indian Ocean region met for the first time and agreed to:

- Formulate three proposed pilot projects that (1) target high-priority phenomena of interest in coastal waters that are important to at least one of the six goals of GOOS and (2) require regional (multi-national) to global approaches to improve the ability to more rapidly detect changes and/or to provide timely predictions of changes.

- Initiate planning to establish a network of coastal laboratories for internet-based data and information exchange relevant to important environmental and ecological variability and change (sea level, river and stream flows, habitat modification, biodiversity, etc.). This will be the first step toward establishing the data communications infrastructure that will be required to build the data-management infrastructure for the coastal component of IOGOOS.

- Establish a Development Committee that will (1) oversee the development of pilot projects, including the coastal laboratory network, and (2) serve as a point of contact for the ocean–climate component of IOGOOS and other bodies interested in the development of the coastal component of IOGOOS (other regional bodies, research programs important to the development of IOGOOS, etc.).

To achieve these goals, it was agreed that a representative from each country would briefly describe 2–3 phenomena that are accorded the highest priority in the country. The presentations are summarized below. This provided the basis for selecting 2–3 phenomena that are (1) high priorities for the Indian Ocean region in terms of their impact on the socio-economics of the countries in the region; (2) are feasible; and (3) make good subjects for pilot projects that would demonstrate the effectiveness of the GOOS approach and would therefore be likely to attract funding.

The Breakout session considered a long list of potential phenomena of interest which included coastal erosion and flooding, loss of habitat and biodiversity, nutrient pollution, sustainable fisheries, chemical contamination, invasive species, aquaculture practices, harmful algal blooms, and safety of life at see. A consensus was reached that pilot projects should be developed for (1) more-rapid detection and timely prediction of coastal erosion; (2) more-rapid assessments of the distribution of habitats and species diversity; and (3) impoved forecasts of sustainable levels of shrimp harvests.

Initial plans for the three pilot projects are described below in section 7.3.

6.2.1 **Country Reports on Priority Phenomena in the Coastal Zone**

Each country informed the Workshop on the key coastal-zone issues of greatest concern to it. Brief summaries of each country report follow:

Mauritius

Coastal erosion: The main causes are cyclones, sea-level rise, human activity, notably coastal urbanization and other hard coastal infrastructure. In Mauritius, 27 sites are affected, of which 7 are critical.
Loss of biodiversity: A number of habitats are affected, notably mangroves, coral reefs (mainly by inappropriate fishing practices), seagrass beds, and wetlands. Fisheries are also a cause of biodiversity loss. Mauritius is trying to establish a Marine Protected Area to conserve biodiversity.
Marine pollution: The main sources are land-based, notably sewage, agrochemicals, industrial wastes, oil spills, and nutrients. Sand mining has been a problem, but is now stopped. There is a significant impact of dirty ballast water from maritime shipping.

Rodrigues

This small island has similar problems to those of Mauritius, although the causes are different; in addition, there is significant soil erosion. Thirteen sites are affected, of which 3 are critical. Harmful algal blooms do occur and there are fish kills that are often seasonal, but there is still no identified cause.

South Africa

Overexploitation of inshore fish and invertebrate stocks: This occurs in the marine and estuarine environments; the abalone resource is especially affected and there is particular concern for endemic species associated with reefs. The region is usually oligotrophic.
Impact of human activities in catchment basins: Water abstraction, changes in sediment transport due to retention by dams, increased soil erosion due to inappropriate agricultural practices, changes in water quality due to the addition or reduction of nutrients, industrial and agricultural runoff, and poorly treated sewage are the main impacts. Sand and coastal-dune mining also have a significant impact.
Inappropriate coastal development: This consists principally of urbanization, infrastructure and industry, resulting in physical changes to the coastline, hence the loss or alteration of natural habitat and of biodiversity.

All issues lead to the need for an ecosystem approach involving modeling on various spatial scales. South Africa has a new legal framework, which is assisting in reducing human pressures in the coastal zone.

Mozambique

Sustainable tourism: This requires conservation of beaches, so coastal erosion is very important here.
Coastal pollution: There is a need to understand the impact of the high level of international shipping.
Safety at sea: Many lives are lost by drowning, so there is a need to forecast sea state and to be able to issue warnings to coastal communities.
Fisheries: Forty per cent of the Mozambican economy is based on coastal fisheries, so it is very important to understand the dynamics of the fisheries and the fish stocks. Illegal fishing by foreign fleets is a significant issue.

There is need to improve infrastructure and institutional capacity; most institutions lack mandate and resources, human and material, to address the key problems.

La Réunion

Degradation of marine ecosystems: This is mainly due to the pressure of human activities in the coastal zone and mostly affects the coral reefs, with a loss of biodiversity.
Cyclones: These have a serious impact on the coastal zone due to the subsequent discharge of water and land-based contaminants, and coastal erosion, all amplified by the steep coastal topography and ill-adapted infrastructure.
Coastal pollution: This is due mainly to groundwater seepage of sewage, agricultural herbicides and pesticides.

Thailand

Overexploitation of fisheries resources: This is now widespread, covering key benthic and pelagic species, with one important consequence being the adoption of illegal fishing methods (e.g., explosives and poisons).
Degradation of coastal ecosystems: Thailand has lost 50–80% of its mangroves in the past 50 years as result of coastal construction, prawn farming and coastal agriculture. Coral reefs in the Andaman Sea have suffered the impacts of offshore tin mining (which causes excessive water turbidity), sand mining (which causes excessive sedimentation and water turbidity), logging, and destructive fishing methods. Seagrass beds have also been lost as a result of inappropriate fishing practices, of sedimentation due to inappropriate agricultural and coastal-engineering practices, forest clearance, and urban runoff.
Coastal erosion: This is due to natural storms and coastal construction.
Coastal water pollution: This is mostly due to effluents from coastal industries, urban wastes, oil spills, and tarballs.

Australia

Increased nutrient concentrations: The natural environment is highly oligotrophic, hence very susceptible to the impact of nutrients introduced as a result of human activities.
Habitat alteration and loss: Also due largely to human activities, notably construction.
Marine pests: Bio-invasions from ship ballast water and hull fouling are believed to have significant impacts on native species and biodiversity.
Contaminants: Also due largely to human activities, notably industry and domestic waste discharge.
Turbidity: There is decreased water clarity in the coastal zone.

Tanzania

Degradation of ecosystems and loss of biodiversity: The ecosystems mainly affected are coral reefs, seagrass beds, and mangroves. The degradation is due to overfishing and improper fishing methods, and overexploitation of the mangroves; coral bleaching is also prevalent.
Coastal erosion: This is increasing as a result of sea-level rise, destruction of the mangroves, and destruction of the coral reefs by dynamite fishing.
Pollution of inshore waters: This is due mainly to the improper discharge of wastes. A community-based monitoring program was presented as a possible solution.

Bangladesh

Data: There is a scarcity of data on physical, chemical, biological, and geological parameters relevant to the coastal area.
Coastal pollution: This is mainly due to heavy metals, pesticides, oil, and oil spills.
Habitat destruction in the coastal zone: This is due mainly to human activities, including shrimp aquaculture.
Aquaculture: Shrimp fishing and aquaculture are very important; shrimp aquaculture is also very important.
Coastal flooding: This is a highly significant issue, with huge losses of human life and property.

Two pilot projects were suggested: a study of the Bay of Bengal, based on satellite data; a study of the coastal ecosystem using remote-sensing and in situ data, to evaluate the impact of aquaculture, pollution, coastal morphology, and biodiversity.

Comoros

Overexploitation of the marine environment: The best example is the coral-reef fishery.
Contaminants: This is mainly due to the discharge of human garbage.
Coastal erosion: Although due to natural causes, human activities, particularly sand mining, aggravate the problem.
Protection of endemic species: The most threatened species are the coelacanth and marine turtles; this is mainly because of the high scientific interest in these species, which sometimes promotes illegal trade.

The problems of Comoros are similar to those of other countries, but often have a different cause. The number-one driver of these problems is poverty. There is a need for models and scenarios for decision-making.

Seychelles

Land reclamation: There is increasing sedimentation and, consequently, serious alteration of the coastal marine environment, leading to a drop in water quality, massive death of coral reefs, and loss of seagrass beds and of mangrove forests. Coastal erosion/accretion patterns are also strongly affected. There is a need to build capacity to deal with these issues.
Oil pollution: There is a need to be able to map and model where spills will move. A World Heritage Park in the Seychelles needs to be protected from this risk.

Sri Lanka

A significant proportion of the population relies on subsistence fisheries, and these are adversely affected by:

Coastal erosion: The main causes are sea-level rise, river sand mining, river dams, coastal structures.

Coastal habitat loss: This is caused by changes in land use, pollution, destructive fishing practices, agricultural runoff, algal blooms, sand mining, and freshwater runoff.
Coastal pollution: This includes principally nutrient runoff from the land, and sewage, industrial and solid waste discharge.

Kenya

Coral bleaching: This is widespread, but its impact is now being measured.
Pelagic fish distribution: Benthic species have been overexploited, so there is a need to identify new fish stocks for new fisheries, and to improve fishery management; for this purpose the acquisition of fishery data must be greatly improved. There are also use conflicts between coastal and trawler fisherman.
Coastal erosion: Sea-level measurements are being made at stations operating within the IOC Global Ocean Sea-Level System.
Harmful algal blooms: These are thought to be the cause of recent fish kills; a new program to study these blooms has been started.
Overexploitation of mangroves: This is due to the use of mangrove wood for building and for charcoal production.

Four pilot projects were suggested: pelagic fish stock displacements with respect to the Indian Ocean monsoon; SST monitoring and the relationship between SST and coral ecology and fisheries; improved resource monitoring; capacity-building.

Strong links between IOGOOS and GOOS–Africa are needed; joint modeling and data-management projects might be a good starting point for this.

India

Biodiversity and habitat loss: There is a need to establish a baseline and a monitoring system, and to screen organisms for bioactive compounds.
Coastal erosion: There is a need to set up monitoring stations and to be able to model and predict natural changes; there is also a need to estimate the economic impacts of development.
Harmful algal blooms: An increased frequency of such blooms is observed; there is a need to identify the bloom species and the factors that trigger blooms.

For the adopted pilot projects, there is a need for a participatory approach, to be decentralized and to enable information to move from scientists to communities. For capacity-building, there is a need to focus on training trainers, and it must fit the culture of the country involved.

Madagascar

Overfishing of some marine species: Sea cucumbers and coral-reef fishes are the principal species of concern.
Degradation of the coastal ecosystem: This is due mainly to coastal erosion and estuarine sedimentation, and needs the development of a coastal ecosystem monitoring system.
Coastal pollution: This is due mainly to uncontrolled waste discharge; it compromises the development of tourism and calls for the establishment of a coastal-zone pollution-monitoring system.
Coastal desertification: An increase in the formation of dunes is observed in southern Madagascar.

There is also a need to develop an oceanographic data collection system.

Iran

Habitat modification and loss of biodiversity: This is arising as a result of the development of marine fisheries, but some is due also to an increase in exotic species (possibly in tanker ballast water) and to growing aquaculture production.
Coastal erosion: This is due mainly to the alteration of river flows and the coastal flooding caused by storm surges and cyclones.
Water-quality degradation: This is due to point and non-point sources of pollution, particularly oil spills and nutrients.

6.2.2 **Phenomena of Interest for Pilot-Project Proposals**

In the light of these country reports, the phenomena of interest in coastal waters were prioritized as follows: coastal erosion; habitat/biodiversity; nutrient pollution; sustainable fisheries; chemical contamination; non-native species; aquaculture; coastal flooding; harmful algal blooms; safety of life at sea.

It was decided to develop pilot projects for three of these as follows: coastal erosion; habitat/biodiversity; sustainable fisheries, the latter being preferred to nutrient pollution on the ground that it encompassed a wider range of environmental factors.

6.3 *Breakout Session II: Pilot Projects*

A working group was formed for each of the three targeted phenomena and each was charged with the preliminary formulating of proposed pilot projects.

6.3.1 **Working Group 1: Coastal Erosion**

The Working Group was chaired by Santaram Mooloo (Mauritius) and the rapporteur was Nalin Wikramanayake (Sri Lanka). It proposed a pilot project on Monitoring and Predicting Coastal Shoreline Change. This and the two other pilot projects proposed herebelow (sections 6.3.2 and 6.3.3) were discussed in detail in the Joint Workshop Plenary Session (section 7 below).

6.3.2 **Working Group 2: Habitat/Biodiversity**

The Working Group was chaired by Greg Wagner (Tanzania) and the rapporteur was Mohideen Wafar (India). It proposed a pilot project on Multi-scale Monitoring and Mapping of Keystone Coastal Ecosystems. (See section 7 below)

6.3.3 **Working Group 3: Fisheries**

The Working Group was chaired by Tickie Forbes (South Africa) and the rapporteur was Nicolette Demetriades (South Africa). It proposed a pilot project on Development of a Monitoring and Management System for the Penaeid Prawn Resources in the Indian Ocean. (See section 7 below)

6.4 *Implementation*

The Breakout Session II concluded by forming an IOGOOS Coastal Development Committee (ICDC) with an Executive Committee (* in membership list herebelow) that will (1) promote the development of the three pilot projects and a network of coastal laboratories for data and information exchange, (2) coordinate their development with ocean–climate pilot projects, and (3) provide the focal point for the IOGOOS Secretariat to coordinate the development of the ocean–

climate and coastal modules of IOGOOS. The following individuals agreed to serve on the Coastal Development Committee:

* Greg Wagner (Tanzania), gwagner@udsm.ac.tz (Chairman)
* Nicolette Demetriades (South Africa), mer@biology.und.ac.za (Officer)
* Tickie Forbes (South Africa), forbesa@biology.und.ac.za (Officer)
* Mervyn Lynch (Australia), M.Lynch@curtin.edu.au (Officer)
* Santaram Mooloo (Mauritius) smooloo@mail.gov.mu (Officer)
* Nalin Wikramanayake (Sri Lanka), tomwiks@yahaoo.com (Officer)
* Mohideen Wafar (India), wafar@darya.nio.org (Executive Secretary)

John Keesing (Australia), john.keesing@csiro.au
Obaidul Quader (Bangladesh), oquader@sparrso.org
Ahmed Abdoulkarim (Comoros), cdo.cndrs@snpt.km
Nasser Zaker (Iran), inco@istn.irost.com
David Kirugara (Kenya), dkirugara@recoscix.org
Mika Odido (Kenya), m.odido@odinafrica.net, m.odido@unesco.org
Chantal Conand (La Réunion), conand@univ-reunion.fr
Man Wai Rabenevanana (Madagascar), manwai@dtss.mg
Rezah Badal (Mauritius), moi@intnet.mu
David Filipe Chemane (Mozambique), david@inahina.uem.mz
Sayed Bukhari (Qatar), sbukhari@gisqatar.org.qa
Thomas Genave (Rodrigues)
Michel Evariste (Seychelles), w.agricole@pps.gov.sc, nms@pps.gov.sc
Dan Baird (South Africa), zladdb@zoo.upe.ac.za
Eckart Schumann (South Africa), ocaches@kpe.ac.za
Kamal Tennakoon (Sri Lanka), tkdkamal@hotmail.com

6.5 *Workshop Conclusions and Recommendations*

A small, but important, step has been taken toward the design and implementation of the coastal module of IOGOOS. Based on the "Integrated Design Plan for the Coastal Module of GOOS" used to guide the discussion of how best to initiate the implementation of the coastal module, the initial emphasis should be on the development of IOGOOS pilot projects; to this end an IOGOOS Coastal Development Committee (the ICDC) has been formed. It will work to develop GOOS pilot projects under the auspices of the IOGOOS Regional Alliance and in collaboration with pilot projects for the ocean–climate module of IOGOOS. Active support of the IOGOOS Regional Alliance, the IOC Perth Regional Programme Office, the IOC GOOS Project Office in Paris, the GOOS Coastal Ocean Observations Panel (COOP) and the Ocean Observations Panel for Climate (OOPC) will be required to turn the ideas and current enthusiasm of the participants into real actions. This should include immediate follow up contact by the IOGOOS Regional Alliance, the Director of the Perth Regional Programme Office, the Head of the GOOS Project Office in Paris, the Co-Chairs of the COOP, and the Chair of the OOPC. The IOGOOS Regional Alliance and the GOOS Panels should identify contact persons for the purposes of coordination and collaboration. A process that will ensure the coordinated development of coastal and ocean–climate pilot projects should be established and, initially, this should involve an *ad hoc* group consisting of the ICDC Executive Committee and Drs. Peter Webster and Gary Meyers.

7. JOINT WORKSHOP PLENARY SESSION

Co-chairs: Gary Meyers, Julie Hall
Rapporteurs: Grant Elliot, Ray C. Griffiths

The proposals of the Ocean Dynamics and Climate Workshop and the Coastal Ocean Observing Workshop were presented under three headings: basin-scale issues, regional issues, and coastal issues.

Under the chairmanship of Gary Meyers, the two Ocean Climate and Dynamics Workshop's sessional Working Groups reported to the Conference.

7.1 *Basin-scale Issues*

The pilot projects proposed by the Ocean Dynamics and Climate Workshop's Working Group 1 were outlined in section 5.3.1, above. The conclusions and recommendations are outlined herebelow under the same principal headings.

Argo

An array of about 450 floats is required to meet the Argo program goal (describe ocean temperature and salinity variability down to 40°S, roughly the southern boundary of the Indian Ocean proper). At present there are about 67 floats deployed, but commitments have been made to have about 170 floats in the Argo array by the end of 2003 (see the presentation by Wijffels et al., mentioned above). The Working Group reaffirmed the importance of achieving full initial deployment of the Argo array in the Indian Ocean.

M Ravichandran (Scientist, Indian National Centre for Ocean Information Services, India) will coordinate efforts to fill gaps and make most effective use of deployment assets. All data will be made available within 24 h of capture, via the Argo data system and the GODAE data servers.

Commitments are being sought to deploy the entire array by the end of 2005, but support to maintain the array, subsequently, will have to be found.

Because of the strong high-frequency variability in several regions, the Working Group agreed that studies should be carried out to determine whether modifications to the standard Argo sampling strategy (parking at 2000 m, profiling every 10 days) are needed. Several groups agreed to pursue this matter, making use of the few available moored-profile time-series and various numerical-ocean-model data sets.

Mooring arrays

The Working Group's discussion focused on the combination of moorings that would best address many of the recently identified issues relative to the response of the ocean and its role in determining subseasonal variability, including the Intra-seasonal Oscillation (ISO) and tropical cyclones.

Strong interest was expressed in establishing an array of moorings along and near the equator to help improve understanding and forecasting of equatorial currents, waves, and air–sea processes unique to the Indian Ocean. Understanding the role of ocean conditions and/or ocean–atmosphere coupling in the ISO will be a goal; so will exploring its predictability. If maintained for several years, this mooring array will also begin to define the seasonal variability of the equatorial waveguide.

The four distinct regions of SST anomaly (SSTA) variability in the Indian Ocean are: the northern Bay of Bengal; just off the southern coasts of Java and Sumatra; a wide area of the southern Indian Ocean; and the western Arabian Sea. SST variability in the equatorial Indian Ocean differs from that of the Pacific in that the equatorial waveguide is not the primary area of SSTA variability. There was considerable discussion of the use of moorings to understand and forecast SST variability in the mid-ocean. The primary mid-ocean region is south of the equator, with the northern edge along the thermocline ridge just south of the equator (5°–10°S), and the southern edge between 15° and 25°S. It was agreed that, at this initial stage of exploration, air–sea measurements were the key and therefore surface moorings are required.

The importance of the variability of the Indonesian Throughflow (ITF) on Indian Ocean circulation and SST was recognized. The INSTANT project seeks to establish a five-mooring array to monitor the ITF better.

The particular sites discussed were:

- 50°E at 0°N
- 60°E at 8°S, 0°N
- 65°E (instead of 60°E and 70°E ??)
- 70°E at 12°S, 8°S, 0°N
- 80°E at 8°S, 5°S, 0°N, 2.5°N, 5°N
- 88°–95°E at 5°S, 0°N, 5°N, 12°N
- 105°E at 8°S
- the INSTANT project array
- OOPC Ocean Reference Sites in the Arabian Sea, Bay of Bengal, South Indian Ocean Subduction (as well as the Kerguelen Islands site in the Southern Ocean).

However, the Working Group could not finalize the large-scale open-ocean moored-buoy array design. It did discuss additional mooring sites that in principle can address most of the scientific issues in the CLIVAR science plan. It recognized that so many sites cannot be developed in the short term, however. An ad hoc Working Group of the Tropical Moored Buoy Array Implementation Panel was formed at the close of the Working Group's meeting to pursue design issues relating to the open-ocean moored-buoy array and to set priorities for a staged implementation in the Indian Ocean. The Panel Chairman will seek formal recognition of the Working Group by relevant bodies (e.g., IOGOOS Development Committee, CLIVAR Scientific Steering Group). The challenge for the Working Group is to design the first steps toward a pilot sustained array.

As many sites as possible will measure surface meteorology as well as u(z) (pressure, u, at depth, z), T(z) (temperature, T, at depth, z) and S(z) (salinity, S, at depth, z). The OOPC ORS moorings are also committed to supporting the development and use of biogeochemical sensors.

The Working Group noted that the USA (Pacific Marine Environment Laboratory and Woods Hole Oceanographic Institution) and the Japanese Marine Science and Technology Center (JAMSTEC) surface measurements have recently been investigated. The comparison of TRITON and ATLAS moorings in the western Pacific Ocean showed significant agreement. Nevertheless, the Working Group considered it necessary to establish the comparability of data from all moorings that will be deployed as part of IOGOOS, although the cost and feasibility of such a comparison needs to be assessed first.

It also agreed that such moorings should conform to GOOS data policy in order to support GODAE and to increase the quality of operational-oceanography products that will be available to the nations of the Indian Ocean rim. The importance of real-time access to moored observations, in support of operational oceanography objectives, was stressed.

The Working Group noted that substantial ship time will be required to deploy and maintain mooring arrays in the Indian Ocean, making the shared use of available ships very important. Suitable ships may be available, if funding can be supplied.

The proposed moored array will be carried forward as Pilot Projects. Funding will be sought through CLIVAR as well as GOOS, depending upon national priorities. Deployment priorities will be determined by the availability and source of funding.

The Working Group agreed that all observing activities should be coordinated via the JCOMM Ocean Observations Coordination Group.

The mooring-array and the Argo pilot projects will be presented for review to the responsible ocean program steering groups and to other interested groups. In particular: Partnership for Observing the Global Oceans (POGO; Hobart, 22–24 January 2003); IOGOOS Executive Committee (at its first meeting); Asia/Australia Monsoon Panel (AAMP; Atlanta, Ga., 25–27 February 2003); Ocean Observations Panel for Climate (OOPC; Ottawa, July 2003).

Ship-of-Opportunity XBT Strategy

The Working Group endorsed a new SOOP XBT sampling strategy. It was recognized that there should be a change in emphasis from broad-scale, areal sampling to line-mode sampling (high-resolution and frequently repeated lines) progressively over the next five years. This approach will promote synergy with Argo, the surface reference network, altimetry, and moored arrays. India, supported by Australia, will take the lead in establishing the new XBT sections. One will extend across the northern Arabian Sea and the other across the southern Bay of Bengal (see the extended abstract by Gopalakrishna et al. at the above-cited ftp site). There was unfinished discussion of the most appropriate combination of spatial resolution and repeat time between sections. These discussions will continue.

The utility of reporting the XBT results in real time was discussed. Development of a telecommunication enhancement to the XBT SEAS system, using IRIDIUM, which would greatly ease such communication, is well advanced. The Working Group considered that coordination via the JCOMM Ship Operations Team was appropriate.

The sessional Working Group also identified a number of actions on which there is a real, remaining need for further discussion:

The plan to provide the sustained observations required to meet the relevant objectives identified by CLIVAR, GOOS and GCOS include: surface—climate-quality basin-wide SST, surface-wind and sea-surface-height fields and surface reference sites; upper ocean—seasonal and longer-time-scale temperature and salinity fields and certain boundary-current-flow information; water column—decadal-time-scale basin changes in the carbon inventory and carbon distribution, nutrients and tracers and flows over certain sills and off certain shelves.
Integration of satellite and in situ observations.

The Working Group considered that IOGOOS should work toward deployment, maintenance, and sustainability of these observing activities, as well as to carry forward the pilot projects identified above.

Participation of IOGOOS countries in the international GODAE also requires further discussion. Use of GODAE products and other operational ocean products to meet the coastal and climate needs of IOGOOS nations, including feedback to GODAE participants on how to improve GODAE products and services, should be encouraged.

7.2 *Regional Issues*

The Workshop's sessional Working Group 2 considered the regional issues under three main headings outlined in section 5.3.2, above. The conclusions and recommendations are outlined herebelow under the same principal headings. The Working Group comprised participants representing the various Indian Ocean regions—southern Africa, East Africa, South Asia, SE Asia and Australia. It had discussed the questions the Workshop had asked it to address (see section 5.2, above), with a view to identifying a regional project that would take advantage of the availability of ocean analyses and climate predictions.

Although time did not permit answers to all the questions, the Working Group identified a unifying theme involving the utilization of ocean and climate information: activity will take place on global, regional and local levels.

At the global level, international programs, such as CLIVAR and IOGOOS, will develop observing networks, data products and predictions in such fields as meteorology, oceanography and climate.

For applicability at the regional level, the global products will have to be downscaled for practical applications (e.g., agriculture, fisheries). Specific oceanic features such as fronts, upwelling zones or the resolution of sea state and currents may need to be enhanced in the products; and using the products effectively will require regional expertise in risk analysis, better ocean climatology and bathymetric information.

At the local level, management of the risk of climate variability and of change in the marine environment, production for a fish market, coastal erosion etc. will need to be developed.

The Working Group identified three areas in which regional activity may take place.

Exploiting climate predictability

The goal is to enable regional uptake of weather and climate information and predictions by tailoring them to specific management decisions in agriculture, water-resource usage and public safety (e.g., what to plant, how much to fertilize, when to sell or buy stock, how much water to allocate, when to issue a warning etc.). Generalized downscaling, risk management and other services are required. The Working Group identified a number of ongoing projects that could be the kernel of regional activities. The capacity-building required in this area involves targeted training in the application of information and risk management.

Fishery applications

The ocean analyses and predictions will provide: relevant data (e.g., high-resolution SST, altimetry) and integrated analyses to the less competitive fishing nations; ocean data and products that are necessary for an ecosystemic approach to fishery management; data to support fishery research (e.g., impacts of climate change).

The Indian Ocean Tuna Commission, based in Mauritius, was recognized as a good focal point for industry and a channel for promoting best scientific practice and informed decisions. Capacity-building in this area calls for joint end-to-end workshops (ocean–climate–fisheries) to better identify needs and to cross-fertilize ideas.

Ocean data and products

The prominent application areas identified by the Working Group were: oil and gas industry (e.g., WAGOOS Timor Sea Project); coastal erosion; coral reef bleaching; coastal management and vulnerability.

Since the applications tend to be located inshore, enhancement of the observing network is required to address offshore–onshore interactions. This enhancement will provide information to enable statistical downscaling and to give reality to attempts to downscale with models.

Data management will need to consider that application/areas and countries need access to all data, even if the data will be used selectively. The data and products for some specialist users are complex and may include data types that were not used in the past. The data service will also need to be provided to non-specialists in non-physical domains. The concept of data warehousing and clearing is applicable here. The capacity-building identified in this area includes technical aspects of a regional distributed data center and service.

The Working Group concluded that IOGOOS has a real opportunity to address the need for data and information at the regional level. This issue was addressed by the Conference's Data Management Workshop (see section 8, below).

7.3 *Coastal Issues*

Under the chairmanship of Julie Hall, the three Coastal Ocean Observing Workshop's three Working Groups reported to the Conference.

7.3.1 **Working Group on Coastal Erosion**

The Working Group proposed a pilot project on Monitoring and Predicting Coastal Shoreline Change.

Nilan Wikramanayake presented the report. The pilot project has the following characteristics.

Project objectives

Assess historical data and place project sites in their geomorphological and hydrodynamical context; establish a program for monitoring changes in coastal morphology and hydrodynamics, by in situ and remote sensing; establish a data exchange network; develop predictive capability.

Project components

*S*horeline and sea-level monitoring; satellite applications; data-exchange network; monitoring of offshore hydrodynamics; forecasting of nearshore conditions; prediction of shoreline change. Community-based monitoring (community, schools, hotels, local government) will be used as far as possible, with organization, motivation and quality control through a central body, and at various levels of technical sophistication.

Project execution

A phased approach, beginning with assessment and a shoreline monitoring system; incorporation of local funding; then development of analytical and modeling capability as data become available.

Expected products

*S*horeline definition, with quantified variation and trends; sediment budgets for coastal "cells"; GIS showing erosion-prone areas; forecasts of nearshore wave climate; predictions of coastal erosion during extreme events.

Product users

Coastal-zone managers; coastal communities; developers and owners of hotels and housing estates; port and marina authorities and users; the scientific community.

Capacity-building

Satellite-data assimilation; modeling of coastal processes; GIS applications.

International cooperation

Data-management design, data processing and interpretation, and exchange; exchange of expertise in modeling.

7.3.2 **Working Group on Habitat/Biodiversity**

The Working Group proposed a pilot project on Multi-scale Monitoring and Mapping of Keystone Coastal Ecosystems.

Greg Wagner presented the report. The pilot project has the following characteristics.

Keystone ecosystems

Coral reefs, mangroves, and seagrass beds (because small impacts on them lead to larger and more widespread ones; they are cost-effective targets for conservation; there is inadequate information on the extent of loss and rate of degradation).

Project objectives

Monitor the keystone ecosystems by large-scale remote sensing, by small-scale remote-sensing in specific areas, by community-based monitoring at specific sites under the supervision of scientists; and disseminate information to governments, to integrated coastal-zone management programs, to communities and fishermen (especially those dependent on the mangrove ecosystem), tourist organizations, and to the IOGOOS network.

Basic variables to be monitored

Area cover; chlorophyll; suspended sediment in the water column; shoreline; species composition in some habitats; coastal bathymetry.

<u>For coral reefs</u>: community-based monitoring will include benthic cover, in terms of—hard coral, soft coral, dead coral; algae, rubble, sand, rock; macroinvertebrate density (sea urchins, sea cucumbers, starfish, gastropods, bivalves, etc.); fish census (to family or other appropriate major taxon). Scientists will measure in situ: special aspects of biodiversity; nutrient levels; temperature, salinity, dissolved oxygen.

<u>For mangroves</u>: density and diversity of mangrove species; density of main life stages (seedlings, saplings, trees); basal area of mangrove.

<u>For seagrass beds</u>: area cover; species composition; macroinvertebrate density (epifauna only).

Preferred methods

<u>For coral reefs</u>: simplified linear transects, with a minimum of 6–10 transects per reef.

<u>For mangroves</u>: 5-m × 5-m plots, with a minimum of 30 plots per mangrove area.

<u>For seagrass beds</u>: 0.5-m × 0.5-m quadrats, with a minimum of 100 quadrats per bed.

The measurement basis will comprise: long-term time-series measurements made by the community on a regular basis (e.g., every six months or one year) over a long period, along with regular analysis of remote-sensing data; large-scale, spatially synoptic measurements to be taken at the same time with the same method(s) in various places over a wide area.

Expected outputs

As appropriate, baseline data on and maps of the keystone ecosystems (coverage, habitat characteristics, species density, composition and biodiversity); spectral analysis of remote-sensing data; statistical comparisons of remote-sensing and community-based data; indices of change and predictions of important changes; recommendations on conservation and restoration strategies; enhancement of environmental awareness.

Capacity-building

Training of community members involved in coastal ecosystem monitoring in the relevant techniques; strengthening the capacity of the concerned regional, national and local government agencies through acquisition of equipment and staff training in monitoring techniques, data-base management, data analysis and interpretation. Environmental NGOs and community-based organizations (CBOs) may also assist in this.

Institutional and infrastructural development

Development of a network of universities and government offices to help in designing and implementing the project; many universities and governments have environmental monitoring programs, so that sharing information amongst them would help to optimize project design, thus enabling the project to be carried out in many countries in a standardized way. Designation of contact persons in each country to help network people in their country with those in other countries.

Establishment of marine protected areas (MPAs) to act as control areas (unlikely to experience significant impacts of human activities) with which to compare other areas that receive significant human impacts; establishment of reference stations, which would have a use similar to that of MPAs, but, in addition, may be selected so as to represent areas that are least likely to experience natural disasters. In addition, sentinel sites carefully chosen in order to quickly detect change and allow rapid planning of appropriate mitigation measures.

Identification and management of the drivers of ecosystem degradation (i.e., human activities and natural phenomena).

For coral reefs: The relevant human activities are destructive fishing, overfishing; coral mining; nutrient and chemical water pollution; boat transport and anchoring; land-based activities that cause sedimentation. The relevant natural phenomena are coral bleaching (possibly due to climate change), outbreaks of the crown-of-thorns starfish; storms and cyclones.

For mangroves: The relevant human activities are harvesting of mangroves for fuel, building poles and boat-making, clear-cutting of mangrove forests for construction of houses and roads; aquaculture, agriculture and salt-making. The relevant natural phenomena are sea-level rise, storms and cyclones, floods.

For seagrass beds: The relevant human activities are destructive fishing practices (drag nets, trawling), movement of boats and people, land-based activities that cause sedimentation. The relevant natural phenomena are cyclones, storms, excessive rainfall which causes increased sedimentation.

International cooperation

Keystone coastal ecosystems are interdependent over large geographical areas; ecosystem changes in one place will affect other places; therefore, sharing of data on ecosystem condition or change throughout the region will enable governments, integrated coastal-zone management programs, marine protected areas etc. to take necessary action in habitat/ecosystem conservation and restoration planning.

Sustainability

Community-based monitoring, which has a low cost and a high cost-effectiveness, will be required, with community cooperation via government agencies and integrated coastal-zone management programs.

7.3.3 **Working Group on Sustainable Fisheries**

The Working Group proposed a pilot project on the Development of a Monitoring and Management System for the Penaeid Prawn Resources in the Indian Ocean.

Tickie Forbes presented the report. The pilot project has the following characteristics.

Rationale for choosing penaeid prawns

Regional dependence on fisheries; the generally poor state of coastal fish stocks; the high value of the prawn resources; the wide regional distribution of prawns; artisanal and commercial fisheries already established regionally; generally the same species regionally; general availability of catch data; the aquacultural value of prawns; the prawn life-cycle integrates inshore marine and estuarine environmental effects.

Project objectives

Creation of links amongst scientists (coastal laboratories), coastal managers and communities; creation of a central data service/product hub available to all; building of sustainable capacity and infrastructure; monitoring of prawn recruitment and abundance via existing fisheries; determination of effects of local conditions (e.g., freshwater run-off); creation of a link to ocean–climate observations; detection of change in prawn-fishery yield in relation to local and regional oceanic/climatic events.

Measurements/data requirements

Fishery data (catch, in quantity and species composition; effort, in number of trawling hours); chlorophyll; oceanographic parameters (salinity, dissolved oxygen, temperature, currents, nutrients); local physical parameters (terrestrial run-off).

Major drivers of change

Human activities (fishing; estuarine and shallow-water habitat degradation and loss); natural factors (monsoons/rainfall regimes; currents; upwelling/downwelling).

The Conference welcomed the proposed pilot projects and strongly recommended their execution under the aegis of the IOGOOS Regional Alliance. It decided that a mechanism to ensure the coordinated development of the coastal and ocean–climate pilot projects should be established and that, initially, this should be an ad hoc group consisting of the IOGOOS Coastal Development Committee's Executive Committee plus Ed Harrison, Gary Meyers, Neville Smith, and Peter Webster.

8. DATA MANAGEMENT WORKSHOP

Chair: Peter Pissierssens
Rapporteurs: Mika Odido, Grant Ellis

Peter Pissierssens presented a paper on "Ocean Information Technology and How IOGOOS Could Be Involved" and another on "OceanTeacher."

The International Oceanographic Data and Information Exchange (IODE) program was established by the IOC in 1960 to: (1) facilitate and promote the exchange of oceanographic data and information; (2) develop standards, formats, and methods for the global exchange of oceanographic data and information; (3) assist member states to acquire the necessary capacity to manage oceanographic data and information and become partners in the IODE network. Over 60 centers have been established; these include Designated National Agencies (DNAs), National Oceanographic Data and Information Centers (NODCs), Responsible National Oceanographic Data Centers (RNODCs) and World Data Centers–Oceanography (WDCs).

OceanTeacher is a comprehensive self-training and resource tool, designed to assist data and information managers to set up and run the new IODE and other data- and information-management centers. It contains a range of marine data-management and information-management materials, including software, quality control and analysis strategies, training materials, and relevant IOC documents. The kit provides information on global data and information archiving, standard formats, and the software tools to perform many quality control, subsetting, and analytical procedures. The kit is accompanied by manuals and regional data sets used in training courses. It can also be accessed at www.oceanteacher.org.

Mika Odido presented a paper on “Ocean Data and Information Network for Africa (ODINAFRICA)."

ODINAFRICA aims at enabling IOC member states in Africa to develop national capability to: manage ocean data and information; develop national capability to prepare ocean data and information products; provide related services; facilitate access to ocean data and information available from the global IODE data-center network; and integrate African ocean science expertise fully into the global research environment by promoting indigenous ocean research through the development of African ocean and information data bases and related products. The experience acquired by ODINAFRICA could be used in the Indian Ocean as a whole, at least until such time as an analogous body is established for the Indian Ocean, if so decided.

Desiderius Masalu presented a paper on “ODINAFRICA in Tanzania.”

The data center in Tanzania has focused on development of data bases and products for integrated coastal management by involving several institutions in Tanzania. These include a catalogue of library holdings, a directory of marine and freshwater institutions, a metadata base of relevant data held by institutions and individuals in Tanzania.

Rondolph Payet presented a paper on “ODINAFRICA: Capabilities in the Context of Indian Ocean GOOS—Seychelles Experiences.”

The ODINAFRICA data center is creating a marine atlas and has generated products for local applications, such as resource management, using a wide range of data sets from various sources, such as the World Ocean Data-base collection, data from the Seychelles Coast Guard, the Seychelles Fishing Authority and the Climate Data Center.

Mohomudally Beebeejaun presented a paper on “Ocean Data and Information Management in Mauritius.”

The key areas to be addressed by their Mauritius ODINAFRICA data center include coastal erosion, storm surges, tidal waves and sea-level rise. He stressed the importance of data acquisition, archiving and management, and data analysis leading to usable products to help solve many of the serious problems faced by the countries of the Indian Ocean, not least the small-island states.

K. Radhakrishnan presented a paper on “Ocean Data and Information Management in India.”

The Indian National Center for Ocean Information Services (INCOIS) was established in 1999. Several marine institutions contribute to the data bases and products maintained by the Center. The areas of focus include ocean-observing systems, satellite oceanography, modeling and data assimilation, and data management. INCOIS has excellent facilities which can be used for IOGOOS training workshops.

Neville Smith presented a paper on “Ocean Information Technology: New Opportunities for Marine Data Management.”

He emphasized the need to align ocean-data management more closely with evolving information technology. There is a need to improve the telemetry, uptake of technology, mode of data transport, and links with the scientific community, in order to create an efficient and effective data- and information-management system for the ocean and marine environment.

The Workshop then discussed the data and information requirements for IOGOOS and how these could be addressed.

Gary Meyers noted that the data and data products required for the Ocean Dynamics and Climate pilot projects are composed of two streams: (1) large-scale data products and analyses on a global scale (e.g., climate prediction, ocean state, weather products, wave products); and (2) local scale. The data and data products on the local scale are lacking and will require special efforts in the region to develop them. There may also be some problems of down-scaling data products from the large scale to the local scale, but "external" sources (e.g., Global GOOS) could be combined with "local sources" (e.g., IOGOOS), if downscaling problems can be overcome.

Tom Malone pointed out that coastal data is nearly always "local". In general, the diversity of data required for the proposed IOGOOS pilot projects is huge and varies from country to country. In addition, very few data-management systems are available in the region to deal with these data. The challenges will therefore be substantial, but so will be the benefits if the necessary systems can be put in place. A clearing-house mechanism will be necessary to assemble and make available the relevant data. He reminded participants that the Coastal Ocean Observing Workshop had recommended that a network of coastal laboratories, possibly with data-management capability, be established in the region.

Mervyn Lynch informed the Workshop that there is limited experience in the remote-sensing community concerned with the IOGOOS program. Quite independently and to serve their own needs, the wider remote-sensing community has established data centers, sets of data products, quality control procedures, and metadata-base management systems. However, there are some areas of concern, such as the often onerous access to such data, the need for validation of remote-sensing data with field data and their proper integration, product consistency across laboratories for the same sensor, or product consistency between different/new sensors. The Ocean Dynamics and Climate pilot projects would probably be well served by remote-sensing products through a variety of national agencies, but it would be necessary to determine whether products needed to be added or improved in order to fully meet IOGOOS (and GOOS) needs. On the other hand, the requirements of the Coastal Ocean Observing pilot projects were complex and would need special attention. Capacity-building would be essential, taking especially into account questions of compliance with data policy, user training, development of climatological ocean products and GIS, if the IOGOOS Coastal Ocean Observing pilot projects, in particular, are to be successfully carried out.

Peter Pissierssens felt that independent local data management was still a long way off, but ODINAFRICA data centers could help in the Indian Ocean; so could POGO and INCOIS. The present weakness of the IODE data-center system was the still relative separation of the data-management community from the wider user community. Even if co-location is not essential, the integration of data acquisition, management, and access is; in any case, access to data and use of data products must be made fully comprehensible to the users. However, the establishment of new data centers is costly, so it is better to develop or adapt the capabilities of existing centers to specific regional needs, such as those of IOGOOS.

The Workshop concluded that the development of a data- and information-management plan should be included in the terms of reference of the IOGOOS Development Committee.

It recommended that IOC undertake a survey to identify and document in detail all existing ocean-data and management facilities in the region. This will enable the identification of suitable data- and information-management partners able to handle all relevant data types and develop the required data products and services. Particular attention should be given to whether these centers are covering or can cover all data types relevant to IOGOOS.

The Workshop also recommended that IOC approach POGO with a view to obtaining fellowships to enable data managers from the IOGOOS region to undertake internships, although it was noted that data management was currently not identified as a priority area by POGO. Since data management will be an essential component of IOGOOS activities, the Workshop called on POGO to reconsider its position with respect to this matter.

The Workshop noted that OceanTeacher currently focused mainly on delayed-mode data management, and recommended that additional modules be developed responding to the requirements of the IOGOOS Coastal Ocean Observing pilot projects, the Ocean Dynamics and Climate pilot projects, and the relevant satellite applications. The Workshop therefore requested assistance from POGO in identifying suitable content authors within the POGO membership to help produce new modules of OceanTeacher.

The Workshop stressed the need to fully exploit existing data- and information-management facilities before establishing new ones. It appreciated the success of the ODINAFRICA project in assisting African countries to establish national oceanographic data (and information) centers that now provide a full range of user-focused data and information services and products.

Since it was agreed that the ODIN strategy should benefit the entire region, the Workshop therefore recommended the development of an ODIN project for IOCINDIO, complementing ODINAFRICA.

The Workshop noted that resources allocated to data and information management were often minimal at the national and regional level, and strongly urged the member states participating in the Indian Ocean GOOS Regional Alliance to increase their levels of support to ensure sustained, high-quality data and information management.

9. SATELLITE APPLICATIONS WORKSHOP

Chair: Merv Lynch
Rapporteur: Doug Edsall

The Workshop Chairman, Merv Lynch, made a presentation on "Indian Ocean Satellite Applications and Remote-Sensing Capacity-Building."

What does IOGOOS require? First, it is not always possible to remotely sense some parameters some of the time. Among those that are not feasible at all are water nutrients and salinity.

Regarding parameters that can be remotely sensed most of the time, the most useful in the IOGOOS context are: surface currents and ocean color/chlorophyll concentration, including seasonal cycles. Ocean features that are of special interest are cyclone-induced upwelling, primary production, and ocean eddies, although the latter tend to stay put and spin. Satellite remote sensing, at present, can only reveal certain ocean characteristics to a depth of 30 m, at most. About a dozen satellites covering the Indian Ocean are now operating.

Regarding the application of satellite remote sensing in the region, it appears necessary to stimulate regional interest and to identify problems whose solution would be facilitated by satellite remote sensing, and to set priorities. As a first step, it would be useful to construct inventories of experts, of interests, and of existing infrastructure. Training workshops and demonstration pilot projects would help in this sense.

The likely problems lie predominantly in the data acquisition, management, and archiving, in the exploitation of the data and the development of useful data products. Data or data products on some phenomena—fires, floods, severe weather conditions, oil spills, for example—can be made available in real time; but certain kinds of data may be in delayed time, by Internet, for instance, although bandwidth competition on the Net is possible. There is also the problem of integrating the information due to differences in satellite overpass times, in data formats, and data gridding. The volume of data is also enormous, so it is necessary to extract a meaningful message from the data. But this is only the beginning of this problem: the volume will grow rapidly from hundreds of gigabytes, today, to hundreds of terabytes, tomorrow, requiring PCs with speeds of 250 gigaherz to process them.

It is also necessary to decide which possible products are appropriate; for this, it is necessary to know precisely what the problems are. That of fishery management, especially in shallow water, is a common one. And the assimilation of data into models is another; but the question is: which models?

There are still some credibility gaps with respect to satellite remote sensing; and capabilities vary from nation to nation. So capacity-building and training are needed, preceded, however, by an assessment of training facilities.

Four speakers then gave presentations.

Frank Shillington presented a paper on "Remote Sensing in the South-Western Indian Ocean."

The majority of the relevant data come from the SeaWiFS and are held at NASA. These data show that chlorophyll is a better signal for ocean structure than is temperature, but care is needed in choosing the colour palette for the images. Nevertheless, a long-term climatology from archive data is feasible. It has proven useful to produce a trace from the coast out to the chlorophyll 1 mg/m^3 contour as an indicator of coastal primary productivity. The LME (Large Marine Ecosystem) project in the region could channel relevant data/products to IOGOOS.

Shailesh Nayak presented a paper on "Satellite Ocean-colour Applications: a Case Study in the North Indian Ocean."

SeaWiFS and OCM satellites carry ocean-color scanners; the main problem is to remove the signal returned from the top of the atmosphere (about 90%) and use the remaining 10%. Then there is the need to integrate the sea-surface temperature data with the chlorophyll data. Validation experiments show a reliability (of the prediction) of 70–90%. This has, nevertheless, led to 70–200% increases in fish catches, although the pelagic fisheries benefit more than the demersal trawl fisheries from the ocean-color data. Predictions generally remain valid for about five days, so there is a need to extend this validity period.

Although the coral reefs and mangroves are being monitored, it is not easy to show changes in mangrove species composition. Coral bleaching can be detected because the reef flat is usually taken over by macroscopic algae. Sediment dynamics, coastal erosion and the tidal front are detectable, as is coastal-zone pollution to some degree, insofar as it can be associated with the sediment dynamics. Coastal-zone flooding and cyclone damage are detectable. Harmful algal blooms are detectable by the infra-red response at the sea surface. Water clarity (measured by the diffuse attenuation and reflection of down welling irradiance) is an important parameter with respect to tunas and to photosynthesis.

It is clearly very important to ensure that the data products are useful and made available at the right levels: societal, national, and of international organizations.

Nasser Zaker presented a paper on the "Application of Satellite Oceanography in the Persian Gulf—and the Current Status."

Present capabilities cover: coastal-zone and oceanic applications up to the regional level; and hazard assessment—storm surges, oil spills, flooding, habitat mapping. Iran's satellite remote-sensing capabilities are limited; at present it receives data from NOAA. In the region, such capabilities are limited to Oman, and there are satellite-receiving facilities in Kuwait.

The priorities for Iran are habitat, pollution, and coastal-zone mapping, and the needs are for increasing public awareness, capacity-building, data and information exchange within the region and with the outside world. There is a low level of expertise; fisheries still do not make use of satellite remote sensing. Hence there is a need for training courses, to establish a national oceanographic data center and a regional oceanographic data center for the Persian Gulf. It is also desirable to increase intraregional cooperation, possibly through a joint regional pilot project.

Merv Lynch presented a paper on “Remote Sensing Data Issues for IOGOOS."

S. Rughooputh presented a paper on "Mauritius Marine and Coastal-Zone Information System".

The main purpose of the system is to provide a large and organized body of information, mostly in the form of maps, as a geographical information system, for planners, scientists, and decision-makers. The information base comprises some 30,000 maps organized in some 12 modules, covering all aspects of the geography of the Island of Mauritius. Some of these maps concern the coastal zone and territorial waters. One likely to be most useful is a shore classification.

Following some discussion of the presentations, the Workshop Chairman summarized the conclusions reached. Regarding data exchange, some of the problems are technical. The hardware and software needs of users need to be determined. Duplication (in data acquisition, processing etc.) must be avoided and made unnecessary by full and free access by all participants in IOGOOS pilot projects to all data in relevant data sources. The needs of the Ocean Dynamics and Climate pilot projects are reasonably well met, now, but those in Coastal Ocean Observing are more difficult to meet, because the algorithms are more complex, and compliance with standards and protocols for measurements and for data products is more difficult to achieve. The priority for the coastal pilot projects is the detection of environmental change (mitigation/degradation), and for this it is necessary to concentrate on quality control of the data.

There are also some pragmatic questions, particularly regarding costs and title to data or data products, to be resolved. High spatial- and spectral-resolution data may be necessary for some purposes but are costly, so hard choices often have to be made.

Planned actions are to prepare:

- a resource directory of satellites and their data products—descriptors, accuracy, spatial and temporal resolution, availability (real time, delayed time)
- an inventory of research and capacity-building centers
- a list of specific needs for capacity-building with respect to scatterometry, altimetry, inshore currents, sea-surface temperature and ocean fronts, and the oceanic water column (chlorophyll *a*, suspended sediments, dissolved organic compounds, light attenuation etc.).

10. ROUND TABLE ON INTERNATIONAL SCIENTIFIC AND TECHNICAL COOPERATION

Chair: Chris Butler
Rapporteur: Doug Edsall

Cdr Chris Butler outlined the purposes and tasks of the US Office of Naval Research International Field Office (ONRIFO) and the possibilities for cooperative research. ONRIFO's particular interest in, and support of, the present Conference was: to identify research facilities and scientific expertise; to suggest areas of research interest and to outline possible funding of future research; to assist in the elaboration of research proposals/projects and in the acquisition of US collaborators for the proposed projects. Cdr. Butler stressed the fact that ONRIFO was interested in collaboration on any state-of-the-art project proposal of specific interest to the US Navy. He invited participants with even tentative proposals to get in touch, at any time during the Conference or afterwards, to discuss collaboration of mutual benefit, leading to co-planning and co-development in the Indian Ocean region.

One potential area of collaboration was Meteorology and Oceanography (MetOc) model verification and validation, given the availability of numerous US Navy global MetOc models. Specific model products could be made available to regional experts in exchange for testing, evaluation and validation using local data. Local knowledge and expertise are considered a substantive contribution in this context. The method of work envisaged is a fully collaborative effort whereby the local expert receives the forecasts and has substantial interaction with the forecast team, potentially including face-to-face visits.

The data types of interest are: physical variables (surface, subsurface and other ocean temperatures, salinity, currents, sea-surface height; waves, bathymetry) and biogeochemical parameters (ocean color, phytoplankton, nutrients, etc.)

Cdr. Butler invited interested countries to consider participation at the national and regional levels, in general, and at the national level, in particular, to identify: from the data types of interest, those that can be monitored at the local level; local experts that are able and willing to collaborate; and historical data.

Interested experts were invited to contact ONRIFO Oceanography, Atmosphere and Space S&T Associate Directors (OAS ADs) by e-mail at oas@onrifo.navy.mil.

Five short presentations on existing programs relevant to the Indian Ocean followed.

Shubha Sathyendranath presented a report on the "Partnership for Observation of the Global Oceans (POGO)."

POGO is a recently founded NGO. Its membership comprises 50 institutions and organizations, including three from the Indian Ocean: the National Institute of Oceanography (Goa, India); Commonwealth Scientific and Industrial Research Organization (CSIRO, Australia); and the University of Cape Town. POGO promotes observations and improvement of scientific knowledge, interprets scientific and technical results for policy-makers, enhances public awareness, and provides training and technology transfer. POGO also supports summer courses, fellowships, workshops, and the Argo program. It is looking for increased participation by Indian Ocean groups and institutions. (POGO website: http://www.pogo.org)

Srinivasa Kumar briefly described a project funded by the Asian Pacific Network for Global Change Research.

In the Indian Ocean region, five countries—Bangladesh, India, Nepal, Pakistan, and Sri Lanka—undertook a coastal-fluxes project comprising small-scale studies of sediment sources and movement, and of the impact of fertilizers in the southeast Asia coastal zone. Capacity-building and regional studies on coastal zone fluxes are also envisaged. (website: http://www.apngcr org)

Yuichiro Kumamoto described the Operation Magellan 2003-2004."

This is a Japanese Marine Science and Technology Center (JAMSTEC) round-the-world expedition starting in Brisbane and ending in Freemantle, Australia, in which hydrographic and benthic sampling will be carried out in the southern hemisphere, in all three major oceans. JAMSTEC is seeking scientific participation of scientists of the IOGOOS region in the Indian Ocean leg of this cruise. (JAMSTEC website: http://www.jamstec.gov.jp)

Mark Jury presented three regional pilot projects: Storm surges in the Bay of Bengal; the Western Indian Ocean Marine Application Project (WIOMAP); and the Indian Ocean Moored Array Project (I-MAP)."

These projects are part of the Indian Ocean Observing Strategy. The Bay of Bengal storm-surge project is important because of the tremendous loss of life and property from such surges. IMAP is proposing nine deep-sea moorings, involving Australia, France, India and the USA. WIOMAP seeks to enhance coastal observations and the training of local people in oceanography and meteorology. I-MAP also involves WIOMAP countries.

Tony Ribbink presented a project on "A study of the coelacanth off the east coast of southern Africa."

The wide interest in this "fossil" fish facilitates its ecological study, which in turn provides a good basis for environmental assessment and monitoring of part of the coastal zone, promotes public awareness, and facilitates relevant capacity-building.

As a result of the Round Table, several project proposals were discussed and received by ONRIFO.

11. IOGOOS MEMORANDUM OF UNDERSTANDING

Chair: Patricio Bernal
Rapporteur: Ray C. Griffiths

Dr. Harsh Gupta briefly reviewed the draft Memorandum of Understanding (MOU) governing the creation of the IOGOOS Regional Alliance, after which the Chairman invited substantive comments on the draft, article by article, inviting speakers to concentrate only on wording that might impede signature. He reminded participants that the formal signing ceremony was scheduled for 5 November.

The main issues raised were:

Should the document be simply an MOU or rather an Agreement? It was agreed that an Agreement was a more formal text than an MOU and would require more formal consideration, and signature, at a governmental level.

Should the document be fully compatible with preceding texts, notably that adopted at the Meeting of Indian Ocean Principals, in New Delhi in November 2001? It was agreed that, while the preceding texts should be taken into account, the MOU could and should stand on its own.

Should the MOU recognize specifically and apply the principles already developed by GOOS, especially with respect to data policy? It was agreed that GOOS principles apply to all GOOS activities, including data acquisition and exchange.

Should voting at IOGOOS meetings ensure equal voting power, where relevant, for all member countries regardless of the number of institutions or agencies a country may have as members of the Alliance? It was stressed that no country should have more than three member agencies/institutions and that these were committed to cooperate fully in the overall interest of the Alliance.

It was agreed also that the Alliance could, if it so wished, invite the Chairs of IOCINCWIO (Intergovernmental Oceanographic Commission's Regional Committee for the Cooperative Investigation of the North and Central Western Indian Ocean) and IOCINDIO (IOC Regional Committee for the Central Indian Ocean) to its Annual and General Meetings, in addition to the Head IOC Perth Regional Programme Office.

For the signature of the final memorandum of understanding on IOGOOS, Dr Ranadhir Mukhopadhyay, Director of the MOI, welcomed the participants. He expressed his general satisfaction with the signing of the MOU and the next step forward in regional cooperation offered by IOGOOS. He believed that good science leads to good technology, which would help to ensure a successful IOGOOS.

Nineteen persons representing national agencies/institutions, signed the Memorandum of Understanding (here grouped by country in alphabetical order, or international organization):

Australia
Neville Smith, Bureau of Meteorology, Melbourne
Gary Meyers, Commonwealth Scientific and Industrial Research Organization, Hobart
Merv Lynch, Curtin University, Perth

India
K. Radhakrishnan, Indian National Centre for Ocean Information Services, Hyderabad
Ehrlich Desa, National Institute of Oceanography, Goa
M. Ravindran, National Institute of Ocean Technology, Chennai
Harsh Gupta, Department of Ocean Development, New Dehli

Iran
Nassar Zaker, Iranian National Centre for Oceanography, Tehran

Kenya
Johnson Kazungu, Kenya Marine and Fisheries Research Institute, Mombasa

La Réunion
Chantal Conand, Université de la Réunion

Mauritius
Harry Ganoo, Mauritius Oceanography Institute, Quatre Bornes

Mozambique
Albano Gove, Instituto Nacional de Hidrografia e Navegação, Maputo

South Africa
Mark Jury, University of Zululand
Anthony Ribbink, South African Institute for Aquatic Biodiversity, Grahamstown
Dan Baird, University of Port Elizabeth, Port Elizabeth
Tickie Forbes, University of Natal, Durban

Sri Lanka
Kamal Dharmasiri Tennakoon, National Aquatic Resources Research and Development Agency, Colombo

USA
Sidney Thurston, National Oceanic and Atmospheric Administration, Silver Spring, Md.

Intergovernmental Oceanographic Commission
William Erb, IOC Perth Regional Programme Office, Perth

The full text of the IOGOOS Memorandum of Understanding is given in Annex 4.

Dr. Harsh Gupta, Secretary DOD, India, expressed his satisfaction at the signing of the MoU which would greatly advance regional cooperation in the important field of ocean observation. He assured the participants of India's firm support for IOGOOS, not only through its offer to host the IOGOOS Secretariat in Hyderabad, but also through a wide range of ocean-observing activities, such as the launching of Argo floats, the establishment of mooring sites and a wide range of coastal monitoring.

Mr. William Erb, Head, IOC Perth Regional Programme Office, also warmly welcomed the signature of the Memorandum of Understanding; he confirmed the whole-hearted support of the IOC and the GOOS Project Office, in general, and of the IOC Perth Regional Programme Office, in particular, in the development of IOGOOS and its program of work.

12. FIRST MEETING OF THE IOGOOS REGIONAL ALLIANCE

Chair: K. Radhakrishnan
Rapporteur: Ray Griffiths

The First Annual Meeting of IOGOOS Regional Alliance was held on 8 November 2002.

The Officers of IOGOOS were elected by acclamation, as follows:

Chairman: K. Radhakrishnan (with specific responsibility for the central Indian Ocean)

Officers (with their respective subregional responsibilities):

Johnson Kazungu, for East Africa
Neville Smith, for the eastern Indian Ocean
Harry Ganoo, for the Indian Ocean islands
Tickie Forbes, for southern Africa.

K. Radhakrishnan expressed his gratefulness to the participants for the honor expressed by them in his appointment; he believed that the present Conference had created a good spirit of cooperation, thanks to the hard work of the last two years, and a good basis for future work. In particular, he confirmed the continuing support of the Government of India in the development of IOGOOS, not least through its hosting of the IOGOOS Secretariat at the Indian National Centre for Ocean Information Services (INCOIS), in Hyderabad, for a period of six years beginning 7 November 2002. The cost of running the Secretariat will be met by INCOIS.

The Officers likewise expressed their appreciation of the honor bestowed on them.

In his new role, the Chairman of IOGOOS proposed Srinivasar Kumar as Secretary of IOGOOS, and this proposal was accepted unanimously.

12.1 *Report from the IOGOOS Secretariat*

Srinivasar Kumar provided a brief background to the creation of IOGOOS, referring in particular to the Indian Ocean Principals' Meeting in New Delhi in November 2001, organized by the IOC Perth Regional Programme Office. Twelve Principals recommended the creation of IOGOOS. To give efffect to this recommendation, a Development Committee was formed under the Chairmanship of K. Radhakrishnan (INCOIS, India), with Rondolph Payet (Seychelles) as Vice-Chairman. The Committee was supported by a Secretariat at INCOIS. The Committee comprises 24 members, from 14 countries, but other countries also expressed a real interest in participating. The Development Committee expanded on the draft Indian Ocean Observing Strategy, originally drafted by the IOC Perth Regional Programme Office. This Strategy is underpinned by the intention to anchor IOGOOS firmly in the IOC Global Ocean Observing System (GOOS). It also drafted the Memorandum of Understanding on IOGOOS.

Satish Shetye briefly reviewed ongoing GOOS activities in the Indian Ocean region on which the proposed Strategy is based; a summary of the Strategy is given in the section on Overview Presentations reflecting the presentation by Erhlich Desa.

William Erb stressed the importance of ensuring that the IOGOOS Strategy be actually implementation by IOGOOS; the Strategy can be expected to evolve as experience is gained in its implementation.

The IOGOOS Regional Alliance adopted the Strategy as presented at the present Conference.

12.2 *IOGOOS Planning*

12.2.1 **Administrative Matters**

The IOGOOS Regional Alliance decided as follows:

For activity planning purposes, the Secretariat should open a Membership Register, complete with address, telephone, fax, and e-mail for each one, and circulate the list to all concerned.

The Secretariat should open a Bank Account for "IOGOOS Central Fund" by 25 November 2002 and communicate this fact to all Members.

The calendar year shall be the Alliance's financial year.

A subscription fee of US$500 should be paid by the Members of the Alliance by 5 January 2003; however, those joining after 31 May 2003 would only be obliged to pay US$250 for the rest of 2003.

The Alliance's Second Annual Meeting should be held in 2003, but the venue is still to be decided. Johnson Kazungu suggested that Kenya might be able to host it, but he would have to explore that possibility. A Meeting of Officers should be held immediately prior to the Annual Meeting at the same venue.

12.2.2 **Organizational Matters**

The Alliance decided the following division of responsibilities among its Officers:

K. Radhakrishnan—overall, for the central Indian Ocean; the Strategy, program planning, budget

The Officers, each in a major subregion of the Indian Ocean, will be responsible for: follow-up of major projects in the fields of Ocean Dynamics and Climate and Coastal Ocean Observing; data management; capacity-building, and financial scrutiny/audit, as follows:

- Johnson Kazungu— for East Africa;
- Neville Smith—for the eastern Indian Ocean
- Harry Ganoo—for the Indian Ocean islands
- Tickie Forbes—for southern Africa.

The Strategy and the recommendations of the present Conference will be the basis for the IOGOOS program of work

To assist the formulation and execution of its major projects, the Alliance decided to consider several possible actions:

- The organization of a joint Ocean Dynamics and Climate and Coastal Ocean Observation Workshop to develop a sound overall coordination of IOGOOS projects (possibly in May 2003)
- The nomination of a Project Coordinator to ensure effective follow-up
- The creation of an IOGOOS bulletin
- Improvement of the IOGOOS website.

12.2.3 **Capacity-building in 2003**

The Alliance was informed of the following planned (but not yet confirmed) activities:

IOC–WIOMSA (Western Indian Ocean Marine Science Association) training course on remote sensing, in La Réunion
IOCINDIO training course along similar lines
ISRO (Indian Space Research Organization) is also intending to hold such a training course at ISRO, Ahmedabad

12.2.4 **Communication**

Four modes were considered viable:

- An e-mail network comprising Alliance members, IOGOOS national focal points and experts
- The proposed IOGOOS Bulletin
- The IOGOOS Web Site (currently assured by INCOIS under www.incois.gov.in)
- Correspondence.

12.2.5 **Major Immediate Events**

The upcoming events considered to be highly relevant to the development of IOGOOS were indentified, as follows:

- GOOS Regional Forum, 2–6 December 2002, Athens, Greece
- POGO–IV, 22–24 January 2003, Hobart, Australia
- GOOS Steering Committee, 26–28 February 2003, Capetown, South Africa
- ARGO Science Team, 4–6 March 2003, China
- I-GOOS–VI, 10–14 March 2003, Paris, France
- IOC Assembly, June 2003, Paris, France

12.3 *Any Other Items*

The Head of Ocean Services, IOC, expressed the strong interest of the IOC Committee on International Oceanographic Data and Information Exchange (IODE) to cooperate closely with the Indian Ocean GOOS Regional Alliance in its field.

The Chairman of IOCINDIO expressed an analogous interest.

The Chairman of the Joint IOC–WMO Technical Commission for Oceanography and Meteorology promised his Commission's full support to and collaboration with IOGOOS.

Seychelles and Mozambique representatives expressed their interest in joining the Indian Ocean GOOS Regional Alliance in due course.

The Chairman, in summing up, stressed the view that the Alliance would collaborate closely with all the concerned IOC regional bodies. He felt it would be vital for the Alliance to get the support of universities and other relevant institutions, with a view to building up a new corps of regional expertise for ocean/climate monitoring.

He also called on the countries represented in the Alliance to establish national IOGOOS Committees with a view to developing the appropriate national activities in support of the Alliance.

The Chairman supported a suggestion by William Erb that the names of the Working Groups and of the Alliance's Officers be put on the IOGOOS website, and that other IOGOOS meetings should be arranged in close association with the Annual Meetings of the Alliance. He also welcomed a suggestion by Vishnu Sondroon (Mauritius Oceanography Institute) that the Alliance should adopt a logo.

13. COORDINATION OF GOOS REGIONAL ALLIANCES

Chair: William Erb
Rapporteur: Ray Griffiths

13.1 *Global Ocean Observing System–AFRICA (GOOS–AFRICA)*

Desiderius Masalu made a presentation, with particular reference to a Regional Ocean Observing and Forecasting System for Africa (ROOFS–AFRICA).

GOOS–AFRICA brings an African dimension and contribution to the Global Ocean Observing System.

It aims to build up a Regional Ocean Observing and Forecasting System for Africa (ROOFS–AFRICA) which will develop new capabilities in the use of remotely sensed data, in situ ocean measurements and observation/validation networks, coastal and marine modelling and forecasting, and delivery systems for user products. It will thus contribute to the capacity-building (training and technology transfer) essential for the proper development, management and protection of the socio-economically important coastal and marine environment of Africa. ROOFS–AFRICA will work interactively with relevant regional and national programs, such as IOGOOS.

Twenty-six African countries participate in GOOS–AFRICA: Angola, Benin, Cameroon, Comoros, Congo, Côte d'Ivoire, Gabon, Gambia, Ghana, Guinea, Kenya, Madagascar, Mauritius, Mauritania, Mozambique, Namibia, Nigeria, Senegal, Seychelles, Sierra Leone, South Africa, Tanzania and Togo. GOOS–AFRICA is, however, open to the other interested African countries, and works with interested African institutions, United Nations agencies, bilateral and international development agencies.

Priorities issues for GOOS–AFRICA are: (1) sustainable use of living marine resources; (2) management of key habitats and ecosystems; (3) coastal erosion; (4) pollution, including land-based sources and marine pollution; and (5) socio-economic benefits to be derived from the development of the ROOFS–AFRICA.

Work on these priority issues will be enabled through four inter-related technical activities: (1) improving the African Network of In Situ Ocean Measurements and Observation Validation, with particular emphasis on the Sea-Level Network; (2) improving access to remote-sensing technology and information; (3) validation and forecasting modelling; (4) development of an end-user interactive information delivery system.

The focal point of GOOS–AFRICA is the Chair and coordinator of the Coordinating Committee, Justin Ahanhanzo (j.ahanhanzo@unesco.org).

GOOS–AFRICA is also keen to collaborate with IOGOOS in capacity-building for African coastal and island states of the Indian Ocean through training courses and regional workshops. A GOOS–AFRICA project proposal has been submitted to donors for funding consideration.

13.2 *Western Australia Global Ocean Observing System (WAGOOS)*

Ray Steedman (steedman@cwr.uwa.edu.au, rksteedman@iinet.net.au) gave a presentation on WAGOOS.

IOC, with the support of the Commonwealth and the State Governments of Australia, through the Bureau of Meteorology and the Department of Industry and Technology (Western Australia), respectively, has established an IOC Regional Programme Office in Perth. The private sector and individuals with an interest in ocean science, engineering and management have been meeting regularly since November 2000 to develop and implement WAGOOS which is being constituted as an incorporated body to afford appropriate protection for members.

The WAGOOS goal is to establish GOOS activities in Western Australia (WA) to benefit the State and Australia and the GOOS community of nations.

Consistent with this goal, a preliminary strategy for the period 2002 to 2007 has been developed. The outcome is expected to be a unified regional network that systematically acquires, integrates and distributes observations, analyses, forecasts and other useful products to users throughout Western Australia and its adjacent seas.

The WAGOOS region hosts many important industries, including oil and gas operations, and fisheries, and is of national strategic importance. The key WA stakeholders in this region have identified several important drivers for research and development: a safe and secure operating environment; management of risk, particularly of risk to the environment; and development of efficient and cost-effective structures and operating methods.

The development of best practice in safety and environmental management is a high priority and this requires knowledge and a detailed information database.

WAGOOS is about to commence its first project in the Timor Sea, after having identified strong scientific, engineering and commercial interest in the oil and gas basins along the southern continental shelf and slope of the Timor Sea.

The Pacific–Indian Ocean Throughflow (PIT) project has been established in the Timor Sea as the focus area to exploit synergy and increase efficiency and effectiveness of a range of ocean-observation, modelling and related regional projects.

The initial focus will be the physical ocean state in the Timor Sea region, from the high-frequency and fine-structure of internal waves and bottom turbulence, to the low-frequency, large-scale patterns of climate.

The Project will, inter alia:

- promote coordination of oceanographic work in the region, including the further development of ocean-circulation models for the region
- support the CSIRO in measuring Pacific–Indian Ocean (Indonesian) Throughflow rates and promote understanding of the structure of the Throughflow, especially the core current
- support the development of an array of instrumented moorings across the Australian continental slope to obtain structural information on the Throughflow core
- encourage accurate tidal-measurement programs, improved tidal analysis, re-evaluation of tidal constants, and reference levels for interpretation of altimeter data
- encourage better theoretical understanding of the internal waves and solitons of the region.

13.3 *South-East Asia Global Ocean Observing System (SEAGOOS)*

Fredolin Tangang gave a presentation on SEAGOOS.

The following countries are participating in SEAGOOS: Australia, Cambodia, Indonesia, Malaysia, Myanamar, the Philippines, Thailand, and Vietnam. The region is characterized by numerous small seas.

SEAGOOS priorities currently lie in CLIVAR, coastal dynamics and pollution, ecosystems, and fisheries. Climate variation is important on the seasonal scale (featuring tropical storms) and the interannual scale (featuring droughts and floods).

SEAGOOS countries have had long-term cooperation with WMO in the field of marine meteorology, but less in the field of operational oceanography. However, SEAGOOS is developing this aspect, particularly through its South-East Asian Center for Atmospheric and Marine Prediction (SEACAMP), which is running a South China Sea storm-surge, wave and circulation pilot project with JCOMM. The establishment of a "numerical minilab" for wave and storm-surge forecasting, in Kuantan, Malaysia, is in planning, as well as a "high-level" meeting to build awareness.

The Chairman, K. Radhakrishnan, stressed the relation of these regional activities to IOGOOS.

It was proposed and agreed that each regional GOOS alliance should do three things:

- Cooperate closely with national meteorological offices and national ocean data centers in the execution of GOOS pilot regional projects
- Link their websites
- Send a representative to the meetings of the other regional GOOS Alliances.

A proposal to create an IOGOOS marine journal was considered premature in view of the existence of a number of appropriate journals in the marine field.

14. WESTERN INDIAN OCEAN MARINE APPLICATIONS PROJECT (WIOMAP)

Chair: Peter Dexter
Rapporteur: Sachooda Ragoonaden

Peter Dexter and Sachooda Ragoonaden briefly informed the Conference on WIOMAP which had met immediately prior to the present Conference on 1–2 November 2002.

Nine countries are participating in WIOMAP. Its creation was preceded by a survey, in 1997, of the relevant institutions in the Indian Ocean region, followed by an expert mission in 1999. The WIOMAP project was drafted in 2000 and reviewed in 2001. It covers operational meteorology, marine safety and fisheries; weather forecasting and disaster preparation. It is aimed at providing services, facilitating marine communication and capacity-building, and developing an observational network and specialized regional marine applications centers. It is planning regional marine applications to be implemented in 2004–2008.

The work of WIOMAP will be carried out technically using ships, moored and drifting buoys, Argo floats, and sea-level gauges. Organizationally, the work will be pursued through expert groups and coordination committees. To this end, WIOMAP works closely with JCOMM which provides the necessary intergovernmental coordination in the management of marine meteorology and oceanography in an analogous way to the WMO Commission on Marine Meteorology in the field of operational meteorology. JCOMM also services the Convention on Safety of Life at Sea (SOLAS) in respect of sea ice, waves, surges and pollution.

15. ADOPTION OF THE CONFERENCE STATEMENT AND CLOSING CEREMONY

Co-Chairs: William Erb, K. Radhakrishnan
Rapporteur: Ray Griffiths

The Conference Statement, which appears in section 3 of the present report, was adopted unanimously.

The IOGOOS Conference Chairman, K. Radhakrishnan, felt that the Conference had motivated the participants and the Indian Ocean and other interested countries strongly to consolidate GOOS and make it grow. He paid special tribute to Angus McEwan for all the guidance he had given, particularly at the Indian Ocean Principal's Meeting in November 2001.

He then invited the Workshop Chairmen to report briefly to the plenary on the achievements of their respective Workshops.

William Erb, speaking on behalf of Gary Meyers (departed), said that the Ocean Dynamics and Climate Workshop had moved GOOS activity in this field greatly forward and would ensure a sound basis for future growth.

Mohammed Wafar, speaking on behalf of Tom Malone (departed), stressed the fact that the Coastal Ocean Observing Workshop had revealed the eagerness of the participants to cross barriers as a direct result of their learning that many of the coastal problems in the region are shared; the Workshop had therefore provided a great opportunity to develop regional cooperation in this field.

Mika Odido, speaking on behalf of Peter Pissierssens (departed), said that the Data Management Workshop had recognized the challenges: the diversity and huge volume of the data, which called for rapid evolution in the application of the latest information technology. To do this, there was a need to survey present regional capabilities and incorporate them into a complete network within a regional data-management system.

Merv Lynch, speaking for the Satellite Applications Workshop, noted that the role of remote sensing had been embraced more vigorously than he had expected. The principal needs now were to disseminate more widely the available remote-sensing information, facilitate access to it and its exploitation. An inventory of regional capabilities for IOGOOS purposes is needed, with substantial capacity-building to make this effective and to produce high-quality data products and interpretation.

William Erb spoke on behalf of IOC; his statement is in Annex 1g. He believed that the objectives of the Conference had been accomplished. The Indian Ocean GOOS Regional Alliance had been established at this Conference, the Chairman and Officers, elected, and its Secretary, appointed. Under Dr Radhakrishnan's leadership, IOGOOS should move forward quickly towards becoming a fully operational observing system for the Indian Ocean. He thanked the Government of India for providing a "nest" for the newest regional GOOS at the Indian National Centre for Ocean Information Services, in Hyderabad.

The Conference had made it clear that there are products and applications that can be delivered to the users in this region, but some things are still needed: pilot projects to pave the way for operational systems; capacity-building in data collection, modeling, and applications; building awareness of GOOS and securing funds for the work; plans for implementation of ocean and climate, and coastal-ocean observing systems; improved use of satellites for IOGOOS applications; and better communication links and infrastructure in the region.

There is a huge number of people to thank in a Conference of this size. First, the sponsors: NOAA, WMO, IOC, CLIVAR, LOICZ, NSF, ONR, DOD, CSIRO, MOI, and Météo France.

Special thanks here go to Chris Butler, of the ONR International Field Office, who gave us our initial boost; to Steve Piotrowicz of NOAA, for his agency's generous support; to the Director of the Mauritius Oceanography Institute, Ranadhir Mukhopadhyay, and to its Deputy Director, Vishnu Soondron, the chief organizer of this Conference, with the close collaboration of Sachooda Ragoonaden who has long been a fine ambassador for the region.

William Erb recorded special thanks to the many Mauritian officials and staff who have been involved with the Conference, working in the Secretariat and outside, in the Local Organizing Committee and elsewhere; and to the Government of India's Department of Ocean Development for having arranged for the O.R.V "Sanya Kagar" to call at Port St. Louis during the Conference and for the participants to visit it.

He thanked the Prime Minister and his staff for their notable contribution to GOOS by securing this beautiful conference site.

He also thanked the Chairmen of the four main Conference Workshops—Gary Meyers (Ocean Dynamics and Climate Workshop), Tom Malone (Coastal Ocean Observing Workshop), Peter Pissierssens (Data Management Workshop) and Merv Lynch (Satellite Applications Workshop), and Chris Butler for the Round Table on International Cooperation in Science and Technology. Also, Mohideen Wafar, who played a key role in organizing the participants in the Coastal Ocean Observing Workshop. And many of the participants who had also assisted by acting as sessional rapporteurs and by leading sessional Working Groups.

Finally, he thanked the participants for their hard work, and particularly those who have agreed to serve on continuing IOGOOS working groups or take the lead in planning. He urged everyone not to forget that their support is critical to the health and well-being of the newest but most important GOOS Regional Alliance.

The IOGOOS Conference Chairman, K. Radhakrishnan, stressed the fact that the Conference had shown that the countries of the region and those especially interested in it had demonstrated a willingness and a capability to cooperate in a large-scale regional action. He invited the Director of the Indian National Institute of Ocean Technology, Muthukamatche Ravindran, Chief Scientist of the O.R.V "Sanya Kagar", to present a memento of the vessel to a number of key figures in the organization of the Conference, on the occasion of the vessel's historic call at Port St. Louis.

Speaking for the host country, Sachooda Ragoonaden noted that when, a year ago, the MOI was asked to organize the Conference, it accepted willingly, but quickly learnt that this would not be an easy task. It would require funding, human resources and a real national interest. He therefore expressed his country's and his institution's thanks for the backing given by the MOI's co-sponsors of the Conference, by the many individuals who had worked to ensure its success. A presentation was then made of a memento of Mauritius to several persons who had made a substantive contribution to the work and the success of the Conference.

Opening and Closing Statements

1a. Opening address by Mr. Harry Ganoo, Chairman of the Mauritius Oceanography Institute

Dr Patricio Bernal, Executive Secretary, Intergovernmental Oceanographic Commission (UNESCO)
Dr Harsh Gupta, Secretary, Department of Ocean Development
The Honourable Rajesh Bhagwan, Minister of Environment
Dr Radhakrishnan, Chairman, IOGOOS Development Committee
Your Excellencies, Members of the Diplomatic Corps
Distinguished Guests
Ladies and Gentlemen

It is my pleasure to welcome you, on behalf of the Government of Mauritius and the Mauritius Oceanography Institute, to this six-day International Conference on Indian Ocean Global Ocean Observing System (IOGOOS) in Mauritius.

I am thankful to the Development Committee of IOGOOS for having chosen Mauritius as its venue for this very important meeting, especially at a time when we are seriously engaged in a number of programs and projects for the protection of our environment. In fact, it is the first time that Mauritius is hosting a meeting of oceanographers. This demonstrates amply the commitment of the Government of Mauritius to the protection of the oceans and ocean resources.

Ladies and Gentlemen,

As we meet here today to reflect on the themes of this meeting which cover a vast array of subjects on coastal, climate and ocean observation, and to map out new directions for the future, the world is facing a number of challenges which have serious implications for the future of mankind as a whole. As global experts in the fields of meteorology and oceanography, you are alive to the fact that the next decades will see a number of transitions in terms of stabilization of the global population, declining energy and mineral resources, and of great environmental change.

These challenges will require an array of new knowledge and technologies to erect a shield of protection—biological, physical, environmental and strategic, in order to ensure our sustainable development. At the same time, they will require an institutional response by governments and agencies and by society at large on the way we do business, with new ways of thinking and new ideas.

Ladies and Gentlemen,

I am no scientist, still less an oceanographer. I have tried to understand the role that the oceans play in our lives and how critical they are to the survival of mankind.

The ocean offers us great opportunities for sustainable growth and development. Studying the ocean therefore is a critical challenge because it holds the key to the Earth’s climate and our well-being on this planet.

The oceans affect us in a broader way because they are our planet’s climate control system. They absorb and store a thousand times more heat than the atmosphere, circulating in partnership with the atmosphere in a dynamic system that regulates rainfalls, winds, storms, cyclones and cyclical climate patterns such as El Niño. Understanding the oceans will be the key to our ability to sustain life, and the quality of life.

We have to constantly improve our knowledge and capacity and understanding of the marine environment through enhanced training. Centres of excellence exist in many parts of the world to help foster international cooperation in capacity building, dissemination of knowledge and experience and as well as for research activities. In Europe, for example, there is a network of over 300 marine research institutes and university departments to carry out ocean research.

It is also vital that there is a proper international legal framework to accommodate the interests of nations in the use of the oceans and their resources. The United Nations Convention on the Law of the Sea is in fact a central element in fostering such cooperation. UNCLOS represents a comprehensive legal regime in the maritime field by reaffirming the rights to freedom of navigation in order to promote international trade and development. It is also a much improved framework for environmental protection, particularly in respect of marine pollution and exploitation of the seabed.

UNCLOS furthermore establishes the extent of coastal States over the seas and the seabed adjacent to their shores; the right of States to conduct marine science research, a balancing of rights between fishing States and coastal States concerning management of stocks; and also for dispute settlement.

The existing multilateral frameworks should however be revitalized to ensure that they develop and implement specific initiatives, such as funding mechanisms to facilitate international scientific collaboration between countries. Joint research projects and information-sharing networks should be other components of their output.

The ecological problems, such as the loss of biodiversity, ozone layer depletion, climate change, shortage of water or marine and coastal zone degradation are becoming more and more widespread. Given the international dimension of these problems, they can be only effectively addressed and resolved within the framework of international cooperation through global partnership in science and technology for development.

But modern science cannot thrive in isolation. The internationalization of research means that technology developments are now global in nature. No one country has the monopoly of scientific expertise nor does any one government have the resources to fund all aspects of scientific research. Research is very expensive. Billions of dollars are being spent by the developed countries in scientific research. If science is to progress, there must be an effective collaboration between governments, interaction between international science communities and closer links between science and business.

At the same time, it is critical that sufficient attention is also given to the specific priorities and problems of the developing countries given their weak scientific and technological base. The developed countries should be able to assist in vital areas such as capacity building, more so as developing countries are those that are more exposed to global tensions, environmental challenges, population increases, diseases and threats to security and public health.

We are aware that 75% of the world's population living in the developing countries share the challenges of a common future. It is important they are given the necessary support to ensure that their future development is placed on a sustainable basis.

Allow me here to make a small parenthesis to state my belief that science looks to the future and is inevitably an attempt to shape the future. Today the road ahead is clouded by the dangers of an over-reliance on traditions, on things that have been, on the past.

My modern mind, my cartesian mind, acutely conscious of the sweep of history and its inordinate use is chronically apprehensive.

Is it really important for me to know that the grandfather of my grandfather came from the black hole of Calcutta or the white hole of Bombay? Should not I rather be more concerned with the future of my children and grandchildren?

My rational mind tells me that I should move resolutely forward and not stand suspended in time—my reasoning blurred in an unbridled emotionalism full of prejudices that stares all the time in the rear-view mirror.

My rational mind urges me to celebrate the future and not the past. And in celebrating the future my rational mind tells me that while I acclaimed the abolition of apartheid in South Africa, I cannot now close the door of opportunities to people just because the colour of their skin is not black or brown like mine.

Opening and Closing Statements

Ladies and Gentlemen,

Science is about looking steadfastly at the future for the benefit of the whole of humanity. It is about setting targets and dates in the future to solve present day problems.

It is not about consecrating the nightmares of the past but about realizing the dreams of the future.

And as we look to the future let me tell you that Mauritius represents an ideal location in this part of the world in any international effort for the protection of the Indian Ocean. The MOI is also developing the right structures and mechanisms to allow it to participate fully in ocean observation strategies and research programs. We would like therefore to reiterate our commitment to support IOGOOS in its endeavour for global coordination of coastal and ocean observing systems.

Ladies and Gentlemen,

The 1992 Rio Summit Declaration represents the most comprehensive and far-ranging set of measures to secure the future of our planet ever agreed by the international community. The results of the Rio Summit are even more significant in that they were concluded at the highest political level.

The Summit indeed provided a new vision of a more hopeful and sustainable future for the human community.

It also established the basic prescription of directions required to ensure that future. The Johannesburg Summit on the other hand, gave an added dimension to global environmental issues as a means to promoting sustainable development.

I have no doubt therefore that this meeting which has brought together a host of professionals and experts from different parts of the world, will provoke thoughtful interventions and harness contributions on the imperatives for the future our planet.

Thank you for your attention.

Opening and Closing Statements

1b. Speech by Dr Patricio Bernal, Executive Secretary, Intergovernmental Oceanographic Commission, and Assistant Director-General of UNESCO

Good morning and welcome everyone.

I would like to offer a special warm welcome to:
The Honorable Mr. Rajesh Bhagwan, Minister of the Environment of the Republic of Mauritius
Dr. Ganoo, President of the Council of the Mauritius Oceanography Institute
Dr Mukhopadhyay, Director of the Mauritius Oceanography Institute
Dr Harsh Gupta, Secretary of the Department of Ocean Development of India, and
Dr Radhakrishnan, Vice-Chairman of IOC

Distinguished colleagues and guests.

It is an honor and a privilege for me to join you here on this peaceful and beautiful island country in the midst of the Indian Ocean. What an appropriate place for the first conference of the Indian Ocean GOOS!

We could not have found a more suitable conference hall anywhere. Yours is a country where peoples of different races, religions and cultures live and work together in harmony. Thus, it is an ideal place to launch our new organization, which will be known as IOGOOS. GOOS is a global programme based on international cooperation, on nations working together for the common good, and the GOOS Regional Alliances, which is what IOGOOS actually is, are responsible for implementing the GOOS program at the regional and local levels.

We live in a world today that is divided in many ways. A world that is experiencing far too many acts of violence, brutality, conflict and terrorism. The causes of these are many and it is not my intention or purpose here today to deliver a dissertation on the state of the world. However, while thinking about this speech, it seemed to me appropriate on this occasion to highlight one aspect of what we do that we usually take for granted. Initiatives such as GOOS are one of the mechanisms that tears down these barriers of dissention, conflict and fear. GOOS brings nations and peoples together to work at a common purpose for the good of all. It helps to define the common problems and needs of a region and then provides the framework for taking joint action to address those needs. Through meetings, workshops and projects, people come together and learn to trust and understand each other's views and to resolve differences.

I am hopeful that IOGOOS will contribute to this ancillary goal as it goes along its way to establish an ocean and coastal observing system for the entire Indian Ocean. Representing UNESCO, as I do, I can easily see how GOOS supports the ideals of the organization to build peace in the minds of people. The ocean, the largest global common on Earth, offers us the opportunity to put into practice these ideals in an area of activity that we are certain will bring direct benefits to humankind.

As most of you may know, particularly if you have read the Indian Ocean GOOS Strategy paper, the IOC has had, in a relatively short time, an influential role in organizing Indian Ocean oceanographic activities. The International Indian Ocean Expedition in the 1960s included many research cruises by many countries, the study of oceanographic processes and the creation of oceanographic institutes such as India’s National Institute of Oceanography. Perhaps most importantly, the concept that oceanography was important to the region and the region was an important part of the global system was firmly established.

Other successful projects followed in the 1980s and 1990s, including the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS), likewise contributing to the knowledge base of the region.

At the beginning of the new millennium, the IOC and the Government of Australia joined together and established an Office in Perth to assist in the development of GOOS in the Indian Ocean as well as the South Pacific. The State Government of Western Australia plays a key role in this partnership and views Western Australia as helping to pin down the eastern boundary of IOGOOS.

Opening and Closing Statements

In early 2000, a large conference took place in Perth on Sustained Observations for Climate in the Indian Ocean (SOCIO), which many of you attended. It laid the foundation for the scientific rationale of Indian Ocean observing and initiated the planning process, which now continues. In November 2001, the IOC Perth Regional Programme Office organized a high-level consultation, the Indian Ocean Principals' Meeting, in New Delhi in November 2001, which reached agreement on the need to establish an Indian Ocean GOOS organization. Dr Gupta chaired that meeting and we must be thankful for his vision and the generous support that he provided to the process, which established the organization. He authorized the setting up of an IOGOOS Secretariat at the Indian National Centre for Ocean Information Systems in Hyderabad. The Secretariat led by Dr Radhakrishnan has overseen the drafting of a Memorandum of Understanding on IOGOOS and an Indian Ocean Observing Strategy that outlines the rationale for IOGOOS. The New Delhi meeting also agreed that a major conference and a meeting was needed to formalize the IOGOOS organization and to bring the people of the region together to plan its future. After only one year since New Delhi, we are here today to do just that. This achievement and the momentum that the whole process has gathered is quite extraordinary.

I am of course very pleased to see that all this has occurred and so quickly. For one thing, I had visited the region four times in just two years, representing IOC, although this is my first visit to Mauritius. More importantly, the IOC has expanded its activities southward and it is now able to more fully address the needs and requirements of this region. This has required financial resources as well as intellectual commitment.

However, we would only be fooling ourselves if we thought that the UN can underwrite the establishment of a truly global observing system. GOOS will only be successful in the Indian Ocean and elsewhere if governments and nations understand its importance and agree to provide the funds and support required to make it work. IOC will continue to help but the real costs involved in running an operational system will have to be met by the region itself. This entails special efforts to raise awareness of the benefits of this endeavor. We hope to demonstrate through pilot activities and awareness-building that an investment in GOOS by the countries surrounding the Indian Ocean basin will bring significant benefits to their peoples and their economies and consequently to the region as a whole.

GOOS is designed with a broad purpose of “public service” in mind, and its development is financed by the member states of IOC. In this sense IOC has a clear advantage as an intergovernmental organization, because, among other things, it can guarantee the universal character of the system, facilitate the exchange of primary data and information and help in the development of capabilities around the world. Of course, the information obtained from these systems, once in the public domain, can be used and is being used by specialized organizations to generate and provide a wide range of applications and services, both public and private.

There are several aspects to this challenge. The first one is institutional development. Member states, and the IOC, need to prepare themselves to meet the needs posed by the development of GOOS. The financing of ocean research has allowed the building of much of what we have today, especially the trial scaled-up runs of prototype systems. However, the financing of the fully operational GOOS cannot depend exclusively on the funding for science. Since no other known source is visible on the horizon, waiting to fill the gap, this shifting of the sources of funding is perceived as a huge menace to the stability of ongoing international research efforts.

The second challenge refers to the use of the data and information generated by operational oceanographic services. Effective use requires the organization of sophisticated systems for processing, modelling and distributing the information. It is not just a matter of securing access to the data, important as this aspect is. It is necessary to establish a highly technical and dedicated organization with the mission of using the data, and producing and distributing final products. These organizations exist today, both in the public and in the private sector.

There are different options here. Is this a development that each member state of the IOC wishes to face independently, or would it be a possible “joint” effort within IOC, organized at a regional scale, for example? Could it be that the global observation of the ocean could be the goal of a private consortium? This brings me to the next point.

The third challenge is economic in nature. Global observations constitute a very particular case of all the observations that can be made. The main feature is the very large scale at which they are collected. At the upper limit, GOOS will be sampling the properties of a single system: the ocean. The sample size is one.

At each spatial and temporal scale there are specific properties of the ocean that are related to that scale and others that “spill over” onto other scales. In theory, full forecasting capabilities would be available only if all scales were properly sampled. This is a huge technical requirement. Conceptually this is not a minor detail. In GOOS, what is a local observation made on the east coast of Africa becomes a “remote and distant” observation for a forecast in the Bay of Bengal, for example, and vice-versa.

Various analyses of GOOS that have been periodically conducted by OECD and others have identified these benefits.

From a practical point of view, there are absolute limits (spatial scale) beyond which appropriability of data from private observation networks faces diminishing returns and a point at which profitability breaks down. Data originating from the local scale, which, from an economic point of view, can be considered a “rival good”, start losing their “rival” character, as they are collected at larger scales, becoming essentially “non-rival goods” at the global scale.

Simply look at Europe and the United States to see how much they are investing in GOOS to benefit their own regions. The IOC and its UN partners, the World Meteorological Organization and the UN Environment Programme, as well as the International Council of Science (ICSU), will continue to support the development process, but the implementation phase requires your countries’ support. This begins with signing the IOGOOS Memorandum of Understanding to become a contributing member.

The Government of Mauritius and its Oceanography Institute have taken their responsibility seriously. They have played an instrumental role in organizing this conference in beautiful Grand Baie. Their conference centre is one of the finest I have seen anywhere and I am sure it will provide us the comfortable and efficient environment needed to hatch our many plans and projects. Dr Mukhopadhyay, Mr Soondron, the Mauritius Oceanography Institute staff and the local organizing committee are to be congratulated on their efforts and dedication.

You may have noticed that this is not a typical conference simply with papers to listen to. It is a series of meetings designed to produce plans, recommendations and objectives for establishing an Indian Ocean observing system. The system will provide new and improved data for understanding climate, coastal processes, resource management, weather and seasonal change and for numerous other applications in the ocean and coastal environment. You will be very busy and the days will be long, but I hope you will have time for some relaxation in between. Each and everyone of you has something to contribute and offer. It might be scientific advice or it might be how your government can support the initiative or assist in launching an ARGO float. I encourage you all to take part-ownership of these meetings and make it your goal to contribute and be involved.

Later in the week you will have an opportunity to visit the Indian Research Vessel *Sagar Kanya* brought here by the Department of Ocean Development and operated by NIO. Theirs was not a luxury cruise but a real statement of commitment. During the cruise they carried scientists from a number of countries, launched ARGO floats and made other oceanographic measurements. We are grateful to India for this very real contribution to the conference and to IOGOOS.

I regret that important business will require me to leave very soon. I sincerely wish you well in your endeavors. I trust you have some time to see more of this enchanting island and I trust that this first inaugural event of IOGOOS will be the first of many.

Opening and Closing Statements

Thank you for this opportunity to address you this morning and “bon voyage” to our new and latest GOOS Regional Alliance: IOGOOS.

Opening and Closing Statements

1c. Speech by Dr. Harsh K. Gupta, Secretary, Department of Ocean Development, India

This is my fourth visit to Mauritius, and every one of them has been remarkable. I came for the first time in December 1983, as the Leader of the Indian Scientific Expedition to Antarctica. The job was very difficult: one of the main objectives being the setting-up of India's permanent base in Antarctica in one Antarctic summer. No other country had achieved this before. With good wishes from all of you, we succeeded. The second visit was in March 1984, when we were returning from Antarctica after successfully having established a wintering station and leaving behind the first Indian wintering team. The kind of welcome that we got is worth remembering. During two days of stay we met all dignitaries. The Prime Minister of Mauritius visited our ship etc. My third visit was on October 2, 2001 to celebrate 100 years of Mahatma Gandhi's landing in Mauritius. I had come with Hon. Minister of H.R.D., S&T and Ocean Development, Dr. M. Manohar Joshi, and the visit was successful.

Today I am here on the occasion of launching IOGOOS. Today, being Deepavali, first let me wish you all a very happy Deepavali. I am sure we will have a very successful IOGOOS meeting and future developments.

Last year we met in Delhi and after a long deliberation decided to develop a Strategy Document for IOGOOS and an MOU to be signed at Mauritius; and India offered a cruise of our research vessel "Sagar Kanya" to Mauritius from India with participants from Ocean-rim countries.

I am very happy to note that all these objectives have been met. Our ship, "Sagar Kanya" is reaching here this evening and I invite you all to visit it. We have several participants from eight countries and on way many oceanographic experiments have been conducted, including the deployment of ten Argo floats. I will not repeat what has been covered by Mr. Bernal and Mr. Ganoo. Ocean observations are extremely important. Let me give a couple of success stories. The Bay of Bengal accounts for almost 1/5 of all tropical cyclones. In India we lost, at times, several tens of thousands of human lives and of course heavy economic losses. Things have change considerably now. With better observation facilities from satellite, data buoys etc., the forecast of tropical storms has become very good and citizens are informed in good time and the loss of lives has reduced considerably. Last year, in May 2001, we had a cyclone at the west coast, where one of our data buoys was just in the centre of cyclone and that made it possible to give accurate forecast of its movement. India has also developed a vision document for oceans which is useful and is available on our website.

Ocean observations are also very important from the strategic point of view – such as our Exclusive Economic Zones and also for the Legal Continental Shelf. Oceans are useful for meeting our energy requirements. We have developed a 1-megawatt Ocean Thermal Energy Conversion (OTEC) demonstration plant on a barge which is to be deployed off Tuticorin in December 2002.

We shall be happy to share all these developments.

As a matter of fact, IOGOOS provides an excellent opportunity for overall development of ocean sciences, understanding of the oceans, and mastering a sustainable use of them.

Let us all work together.

Opening and Closing Statements

1d. Speech by the Hon. Mr. Rajesh Bhagwan, Minister for Environment

Colleague Ministers,
Honourable Members of the National Assembly,
Mr Ganoo, Secretary to Cabinet, Government of Mauritius,
Dr Harsh K. Gupta, Secretary, Government of India,
Dr Patricio Bernal, Executive Secretary IOC,
Dr Radhakrishnan, Chairman, IOGOOS Development Committee
Excellencies of the Diplomatic Corps,
Directors of National and Overseas Institutions,
Distinguished Scientists and Guests,
Ladies and Gentlemen,

I wish to welcome you all to Mauritius on behalf of the Government of Mauritius.
We are very honoured to host this first Meeting of the Indian Ocean Global Ocean Observing System. In accepting to host this conference, Mauritius wishes to demonstrate the importance it attaches to the ocean and the unflinching support it brings to the initiative to build an ocean-observing system in the region.

As we are all aware, the study of the Indian Ocean is important for the countries of the region and outside the region for various reasons. It is important to understand ocean processes for several reasons, namely:

- the optimum exploration and sustainable exploitation of ocean resources
- tuna migration has a direct relation to variation in the sea surface temperature pattern with the season
- air–sea interactions in the open ocean affect also weather globally and regionally; for example, a direct correlation has been found between the sea surface temperature in the Indian Ocean and the rainfall in the region
- the circulation of oceans transports pollutants across national and geopolitical boundaries and can affect regions near and far from where these pollutants originated
- resources in the ocean, such as pelagic species, know no boundaries, traveling from one national water to another.

As coastal states we are largely influenced by the sea and now we are aware of the fragility of our living environment and its sensitivity to climatic change, natural disasters and human impacts. Climatic change and associated sea level rise and tropical diseases can seriously undermine our economy and upset the economic, social and political stability.

The rapid global warming caused by human-induced changes in the atmosphere that is projected by the Intergovernmental Panel on Climate Change (IPCC) would have dramatic effects on the ocean, threatening valuable coastal ecosystems and the economic sectors that depend upon them. The IPCC predicts that storms and other extreme weather events will increase in frequency and intensity, increasing natural disturbances to coastal ecosystems and perhaps reducing their ability to recover.

There is particular concern about the possible effects of global warming on coral reefs. During the intense El Niño of 1997-98, extensive coral bleaching occurred on coral reefs worldwide. While some reefs quickly recovered, others, particularly in the Indian Ocean, Southeast Asia and the far western Pacific, suffered significant mortality, in some cases more than 90 per cent.

As developing nations, we have not been able hitherto to devote sufficient resources to understand the oceanic processes in this part of the world where almost one third of the world population live. We do not have a permanent, systematic, routine and long-term ocean-observation system for assessing the state of the marine and coastal environment and to forecast climate variability and change. Indeed we have been passive spectators to the changes to our oceans and coastal seas.
However, new tools are now available which allow us to play a more proactive role and take advantage of early warnings to protect ourselves and the environment. These tools can detect

changes in the marine and coastal environment and allow observations to be made for more informed decisions that save lives and protect our fragile ecosystem and living 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, forecasted and the electronic distribution of data and information worldwide. This permits an unprecedented global coordination of ocean and coastal observing systems.

The major limitation in making the Indian Ocean understood is the financial constraints of the countries of the region. Few of our countries have the economic or logistical capacity to undertake oceanographic research on their own. However, by working in partnership and sharing resources available in the countries, such work is possible. Opening the research work to other institutions interested in the region and with the assistance of donor agencies it is possible to develop the oceanography in our region. It is possible through regional and international cooperation between our nations to focus effort on and address the most pressing regional environmental dangers.

I think I express the wish of all the countries of the region when I say that equal importance should be given to coastal and oceanic processes. Most of the countries here today, representing the Indian Ocean region, have a large percentage of their population living in coastal areas. These areas are facing increasing pressures from landbased activity due to development, growing populations and global problems such as sea level rise. This particular problem due to global warming will become a real threat to small islands like those in the southwest Indian Ocean. Hence coastal issues need to be urgently addressed. By addressing pressing issues of the coastal states in the region, the IOGOOS has better chances of becoming a successful operational system.

Being one of the oceans where oceanographic understanding is lagging behind that of other oceans, there is yet much work to be done in the Indian Ocean region and I am sure that you will all use the opportunity of this gathering to define the important issues of the area and develop a viable plan for the oceanographic future of this region. However, at the national level Mauritius has taken concrete steps to protect the coastal zone, namely:

- the complete phasing out of lagoonal sand mining
- the updating of the National Physical Development Plan
- the development of an ICZM plan
- studies on wetlands, coastal erosion, islets, sensitive areas etc.

I understand that one of the highlights will be signing of an MOU, a commitment of the nations in this region to synergise their efforts. I hope and I sincerely wish that it will result in increased collaboration in the region. I am sure that projects will be elaborated, strategies discussed and an operational program would be set up to make the IOGOOS a reality. It is our expectation that this conference will see the start of new partnerships and finally enable us to change the reputation of the Indian Ocean from one of the least known oceans to one which is well studied and sustainably managed.

With its strategic location in the middle of the Indian Ocean, multicultural background, and its political, social and economic stability, Mauritius offers an ideal platform for a synergy of African, Asian and Australian oceanographic interests.

To end up allow me to thank [The Minister first addressed his thanks to a number of persons involved in the organization of the Conference: Dr. Ganoo, President of the Council of the Mauritius Oceanography Institute; Dr Mukhopadhyay, Director of the Mauritius Oceanography Institute; Dr Radhakrishnan, Vice-Chairman of IOC; Mr. William Erb, Head of the IOC Perth Regional Programme Office, inter alia]

I would like to specially thank the Department of Ocean Development, Government of India, for having dedicated a cruise on board the O.R.V. "Sagar Kanya" for the occasion. The vessel with scientists of the Indian Ocean rim countries arrived in Mauritius after a number of oceanographic observations in various fields of oceanography, i.e., biology, chemistry, geology, physics on its way from India to Mauritius, via the Seychelles. The O.R.V. "Sagar Kanya" is currently berthed at the Quay A at the Port

Louis Harbour and the public at large and interested organizations will be able to visit the vessel during stay here and learn more about the work done on board.

Thank you for your attention.

Opening and Closing Statements

1e. Vote of thanks by Dr K. Radhakrishnan, Chairman IOGOOS Development Committee

Honourable Minister for Environment, Mr Rajesh Bhagwan; Dr Patricio Bernal, Executive Secretary IOC and Assistant Director-General, UNESCO; Dr. H.K. Gupta, Secretary of the Department of Ocean Development, Government of India; Mr Harry Ganoo, Chairman MOI; Distinguished Delegates, Invitees and Members of the Media,

The entire Indian Ocean community joins me, now, to salute all the individuals and organizations who conceived GOOS, who nurtured it over the last one decade, who demonstrated that GOOS works, who reminded us that we need to pursue it, and who facilitated this major historical event. This will be a major endeavour ensuring synergy in the Indian Ocean to make the least-known ocean the well studied ocean for the benefit of humanity.

This small beautiful country, a confluence of many civilizations, has been a platform for launching several cooperative initiatives in the Indian Ocean region. Honourable Minister, we are grateful to the Government of Mauritius for their gracious offer to host this Conference. Your words of wisdom are immensely valuable to this endeavour—the Indian Ocean GOOS.

Dr. Patricio Bernal, a visionary and a versatile executive, heads the apex intergovernmental body on the ocean—the IOC. We note the global and regional imperatives for an active Indian Ocean GOOS, and the challenges. We will move forward together to realise this.

The international Indian Ocean Expedition was a landmark in the history of this region. Dr. Harsh K. Gupta, a young Scientist of that team is now steering the Indian efforts in ocean development with a vision and missions charted out for the next 25 years. He was a guiding spirit for us to move forward with the setting up of IOGOOS. His generous offer of O.R.V. "Sagar Kanya" for the IOGOOS cruise is gratefully acknowledged.

Chairman MOI, your leadership was extremely important for organizing this mammoth affair. You welcomed all of us to this warmly and ensured an ambience that would facilitate the conduct of the business during this week.

Many organizations came forward to support this Conference by providing financial support and by deputing their precious resource-persons. This support from IOC, WMO, NOAA, ONR, DOD, MOI, NSF, CLIVAR, the 30 countries and the four international organizations was essential for the success of this Conference.

A few individuals came forward to bear the brunt of organizing this Conference: The Chairman and Members of the Steering Committee, the Chairman and Members of the Local Organizing Committee and the IOC Perth Regional Programme Office. A special mention needs to be made of Bill, Vishnoo, Sachooda and Ranadhir who have been flooding us with the information that we needed.

The media has to play an important role in bringing awareness about the oceans and the relevance of the Conference to the common man. I thank the media for working with us to propagate this message. I thank the Indian Ocean Principals who gave me an opportunity to contribute to the cause of the Indian Ocean community.

Opening and Closing Statements

1f. Vote of Thanks by Dr. K. Radhakrishnan, Chairman IOGOOS-Development Committee, at the Signing Ceremony of the IOGOOS Memorandum of Understanding, 5 November 2002

This is a defining moment in the history of the Indian Ocean. This is an emotional moment for everyone present here. It is my privilege to thank everyone who played a role in making this happen—as catalysts, facilitators, enablers, and finally the 19 actors who formally expressed their desire to work together for the cause of science and society.

This is an onerous task; challenges are many; expectations are high; maintaining credibility is important. The concern, cooperation and commitment that was the driving force over the recent past need to be sustained to achieve our goals. I wish you all success. May God bless us to serve humanity better.

Finally, I thank you once again for giving me the opportunity to thank you once again.

Opening and Closing Statements

1g. Statement by William Erb at the Closing Ceremony of the Conference

We have clearly accomplished the objectives of the Conference. The Indian Ocean GOOS Regional Alliance is now in place, with nineteen members and more to come. The Chairman and Officers have been elected and the Secretary has been appointed. Under Dr Radhakrishnan's leadership, we should move forward quickly towards our goal of a fully operational observing system for the Indian Ocean. We also have, thanks to the Government of India, a "nest" for our newest GOOS, at the Indian National Center for Ocean Information Services, in Hyderabad.

Although much work is yet to be done, we have discovered that there are products and applications that can be delivered to the users in this region with the tools that already exist. It is a matter of organizing ourselves to deliver them, and the Conference has identified many people and institutions to assist in this task.

There are some things we still need to do:

- We must have pilot projects to pave the way for operational observing systems
- Capacity-building in data collection, modeling, and applications is necessary
- We must build awareness of GOOS and secure funds to carry out our work
- We must develop plans for implementation of ocean and climate, and coastal-ocean observing systems
- Improved use of satellites for our applications is essential
- We must strengthen communication links and improve infrastructure in the region.

And perhaps most importantly, we are the champions of the people to make IOGOOS work.

There is a huge number of people to thank in a Conference of this size. I must begin with the sponsors: NOAA, WMO, IOC, CLIVAR, LOICZ, NSF, ONR, DOD, CSIRO, MOI and Météo France.

Special thanks here go to Chris Butler, of the ONR International Field Office, who was the first to come forward to give us our initial boost. The generosity and support of NOAA was critical in all this, and Steve Piotrowicz is largely responsible for this, and we thank him.

We sincerely thank all the other sponsors, even if I refrain from mentioning each of them.

You will all have observed by now the dedication and enthusiasm of the staff of the Mauritius Oceanography Institute. Under the guidance of its Director, Dr Mukhopadhyay, MOI arranged the venue, purchased the tickets, secured the hotels, processed the documents and reports, and carried out dozens of other tasks. This was accomplished with smiles and great efficiency, largely under the guidance of MOI's Deputy Director, Vishnu Soondron; he has done a fantastic job, and I give him my personal thanks for making this Conference a success.

Others were involved, not least Sachood Ragoonaden, whom we all know. He has worked on the Conference, as well as the WIOMAP Meeting; he has been a fine ambassador for the region for a long time: many thanks, Sachooda.

Many Mauritian officials and staff have been involved with the Conference, working in the Secretariat and outside, in the Local Organizing Committee and elsewhere. I wish to record my special thanks to them:

Mr Harry Ganoo, Chairman of MOI
Dr Ranadhir Mukhopadhyay, Director of MOI
Mr Sachooda Ragoonaden, MOI Board Member
Mr D. Rochecoute, Manager of the International Conference Center.

Opening and Closing Statements

Likewise to the officers serving the Conference:

Mr V. Soondron (chief organizer)
Mr B. Boyramboli (accounts, travel and logistics)
Mr S. Persand (technical logistics)
Ms S. Ramjanally (chief of the secretariat)
Ms F. Seechurn (secretary)
Mr P Baguant (accommodation, transport)
Ms S. Purusram (typist).

And the supporting staff:

<u>Secretariat</u>
Mr P. Dupré (information technology)
Mr K. Curpen (Conference logistics)
Ms N. Tegally (secretary to Director, MOI)
Ms S. Maunrajoo (document bags, stationery)
Ms R. Boyjaunath (receptionist)
Ms P. Kallichurn (receptionist).

<u>Finances</u>
Mr C. Mauren
Ms R. Sobha.

<u>Technicians</u>
Mr Bhoojhowon
Mr Gajaghar.

As you know, the Prime Minister's Office was instrumental in securing this beautiful conference site. We thank the Prime Minister and his staff very much for this great contribution to GOOS.

It goes without saying that the invited speakers and Workshop chairmen took their work seriously, not least by organizing meetings that have shown us the way forward. The papers presented were extremely good, and we thank you all. I must mention specifically Gary Meyers and Tom Malone who put an enormous effort into organizing their respective Workshops, on Ocean Dynamics and Climate, and on Coastal Ocean Observation. Gary was also a tremendous help in shaping the Conference as a whole. Mohideen Wafar was very instrumental in organizing the participants in the Coastal Ocean Observation Workshop. Peter Pissierssens and Merv Lynch also organized extremely well their respective Workshops, on Data Management and on Satellite Applications, respectively. These were informative and helped define our plans and goals. Many of the participants also assisted by acting as sessional rapporteurs and leading sessional Working Groups, which was critical to our progress here: thank you all. And yet others who helped in many small but useful ways: many thanks, as well.

Each and every one of you—the participants—must be thanked for your hard work, which often extended into coffee breaks and lunch hours. The energy level was obvious as you debated issues and made plans, even during the various receptions offered us during the Conference. Many of you have agreed to serve on working groups or take the lead in planning. To everyone, thank you.

Ray Griffiths, our Conference Rapporteur, will continue his work of preparing the Conference report. With your help, we hope to get it you soon, on the Web and in print.

If you can, I hope that you will find at least some time to see and enjoy Mauritius. Many of you have long journeys ahead, and I trust they will be safe and comfortable. But please don't forget that your support is critical to the health and well-being of our newest but most important GOOS.

Program

International Conference Centre (ICC), Grande Baie, Mauritius

SUNDAY 3 NOVEMBER 2002

1630–1800	Registration	ICC foyer
1700–1900	Ice-breaker *(Courtesy IOC)*	Le Mauricia by the sea

MONDAY 4 NOVEMBER 2002

0830–0930	Registration	ICC foyer
0830–0930	Poster display	ICC foyer
0930–1030	Opening *(Welcome by Chairman MOI; speeches by Executive Secretary IOC, Secretary DOD; inauguration by Hon. Mr. Rajesh Bhagwan, Minister for Environment; vote of thanks by Chairman IOGOOS–DC)*	Plenary Hall
1030–1100	Coffee break	ICC foyer
1100–1105	Local organizer's brief	Plenary Hall
1105–1300	Overview presentations on regional interest in coastal, climate and ocean observing systems *(Organization: S Shetye, K Radhakrishnan)*	Plenary Hall
1300–1400	Lunch break	
1400–1500	Overview presentations on the status of the ocean and climate observing systems *(Organization: G. Meyers, P. Hacker, M. Jury)*	Plenary Hall
1500–1530	Overview presentation on the role of the Indian Ocean in Asian, Australian and African monsoons and climate predictability *(Organization: P. Webster)*	Plenary Hall
1530–1600	Coffee break	ICC foyer
1600–1700	Overview presentation on the Integrated Design Plan for Coastal GOOS *(Organization: T. Malone)*	Plenary Hall
1700–1730	Overview presentation on the GIFTS/IOMI satellite contribution to the Indian Ocean observing system *(Organization: M. Lynch)*	Plenary Hall
1800–1900	Discussion of the draft Memorandum of Understanding on IOGOOS, and of An Indian Ocean Observing Strategy	Plenary Hall

TUESDAY 5 NOVEMBER 2002

0900–1030	Joint plenary of the Ocean Dynamics and Climate Workshop and the Coastal Ocean Observing Workshop Invited interdisciplinary presentations *(Organization: G. Meyers, T. Malone)*	Plenary Hall
1030–1100	Coffee break	ICC foyer

Parallell Sessions

1100–1300	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop *(Organization: G. Meyers)*	Plenary Hall
1100–1300	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop *(Organization: G. Meyers)*	Plenary Hall
1300–1400	Lunch break			

Program

1400–1530	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop *(Organization: G. Meyers)*	Plenary Hall
1530–1600	Coffee break			
1600–1730	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop *(Organization: G. Meyers)*	Plenary Hall

1730–1830	Signing of the Memorandum of Understanding on the Indian Ocean Global Ocean Observing System *(Welcome by the Director of MOI; speech by William Erb; vote of thanks by Chairman IOGOOS–DC)*	Plenary Hall
1830–2030	Cocktail by the sea *(Courtesy Mauritius Oceanography Institute; welcome by the Chairman of MOI)*	Ocean Restaurant

WEDNESDAY 6 NOVEMBER 2002—Parallel Sessions

0900–1030	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop WG 1 Basin-scale contributions WG 2 Regional-scale contributions *(Organization: G. Meyers)*	Plenary Hall B Hall
1030–1100	Coffee break			
1100–1300	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop WG 1 Basin-scale contributions WG 2 Regional-scale contributions *(Organization: G. Meyers)*	Plenary Hall B Hall
1100–1300	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop WG 1 Basin-scale contributions WG 2 Regional-scale contributions *(Organization: G. Meyers)*	Plenary Hall B Hall
1300–1400	Lunch break			
1400–1530	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop WG 1 Basin-scale contributions WG 2 Regional-scale contributions *(Organization: G. Meyers)*	Plenary Hall B Hall
1530–1600	Coffee break			
1600–1630	Coastal Ocean Observing Workshop *(Organization: T. Malone)*	C Hall	Ocean Dynamics and Climate Workshop WG 1 Basin-scale contributions WG 2 Regional-scale contributions *(Organization: G. Meyers)*	Plenary Hall B Hall

1630–1800	Round Table on International Science and Technology Collaboration	Plenary Hall
1800–1900	Launching of the Field Guide to the Corals of Mauritius, by the Hon. Sylvio Michel, Minister of Fisheries	Plenary Hall

Program

THURSDAY 7 NOVEMBER 2002

0900–1030	Joint plenary of the Coastal Ocean Observing Workshop and the Ocean Dynamics and Climate Workshop *(Organization: T. Malone, G. Meyers)*	Plenary Hall
1030–1100	Coffee break	ICC foyer
1100–1300	Data Management Workshop Invited presentations *(Organization: P. Pissierssens)*	Plenary Hall
1300–1400	Lunch break	
1400–1600	Data Management Workshop Invited presentations *(Organization: P. Pissierssens)*	Plenary Hall
1600–1630	Coffee break	ICC foyer
1630–1900	Visit the O.R.V. "Sagar Kanya" (DOD, India)	Port St. Louis harbour

FRIDAY 8 NOVEMBER 2002

0900–1000	Data Management Workshop Invited presentations *(Organization: P. Pissierssens)*	Plenary Hall
1000–1030	Satellite Applications Workshop *(Organization: M. Lynch)*	Plenary Hall
1030–1100	Coffee break	ICC foyer
1100–1105	Local organizer's brief	Plenary Hall
1105–1300	Satellite Applications Workshop *(Organization: M. Lynch)*	Plenary Hall
1300–1400	Lunch break	
1400–1500	Satellite Applications Workshop *(Organization: M. Lynch)*	Plenary Hall
1500–1530	IOGOOS elections	Plenary Hall
1530–1600	Coffee break	ICC foyer
1600–1700	IOGOOS-I meeting *(Organization: K. Radhakrishnan)*	Plenary Hall
1700–1730	Presentation of the WIOMAP report *(Organization: P. Dexter, S. Ragoonaden)*	Plenary Hall
1730–1800	IOGOOS-I meeting *(Organization: K. Radhakrishnan)*	Plenary Hall

SATURDAY 9 NOVEMBER 2002

0900–1030	Regional GOOS meeting	Plenary Hall
1030–1100	Coffee break	ICC foyer
1100–1200	Regional GOOS meeting	Plenary Hall
1200–1230	Closing ceremony Adoption of Conference Statement	Plenary Hall

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IOGOOS Memorandum of Understanding

Memorandum of Understanding on the creation of an Alliance of marine operational and research agencies/institutions/authorities in the Indian Ocean region, hereinafter referred to as IOGOOS, whose Members seek to foster cooperation on the Global Ocean Observing System

NOTING that the lives of at least 1.5 billion people on this planet Earth are profoundly influenced by the Indian Ocean characterized by a fragile living environment that is sensitive to climate changes, natural disasters and human impact,

REALIZING the imperative need to take a pro-active role and concerted actions to understand the ocean and coasts for making informed decisions that save lives and protect living habitats and resources in the Indian Ocean region,

INTENDING to contribute, collectively, to the progress of ocean observations, ocean science and operational oceanography, focussing on these imperative needs of the Indian Ocean region,

RECOGNIZING the important role taken by the Global Ocean Observing System (GOOS) sponsored by United Nations Agencies (Intergovernmental Oceanographic Commission (IOC) of UNESCO; World Meteorological Organization; and United Nations Environment Programme) and the International Council of Science, to facilitate a global coordination of ocean and coastal observing systems and to catalyse formation of alliances between nations to focus effort on their pressing regional concerns,

NOTING the other programs of IOC such as IODE and ODINAFRICA,

DESIRING to establish IOGOOS to provide an organizational framework for planning, coordination and effective implementation of appropriate regional and sub-regional ocean and coastal observing systems and services,

FURTHERING the efforts of the High-level Consultations at the Indian Ocean Principals' meeting held on November 8–9, 2001 at New Delhi that established the IOGOOS Development Committee to lead the process of an Indian Ocean Regional Alliance**,**

the undersigned agree to the following Articles:

Article 1: Creation of IOGOOS

By signing this Memorandum of Understanding, the agencies/institutions/authorities agree to (a) establish IOGOOS, an alliance of marine operational and research agencies/institutions/authorities in the Indian Ocean region (b) become Members of IOGOOS and (c) cooperate in promoting GOOS in the Indian Ocean region.

Article 2: Aims and Objectives

Members of IOGOOS will collaborate and work together for developing programs for the implementation of GOOS in the Indian Ocean and for promoting activities of common interest for the development of operational oceanography in the Indian Ocean region, broadly to:

i. Enhance the ocean observing system in the region

ii. Promote and facilitate efficient and effective management, exchange and utilization of oceanographic data

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iii. Promote programs and projects in operational oceanography and ocean services in the region meeting the requirements of end-users

iv. Strengthen capacity-building for enhancing the capabilities in the region

v. Encourage research to support of needs of users

vi. Develop synergies with other ocean programs and regional GOOS bodies and

vii. Contribute to international planning and promotion of GOOS.

Article 3: Activities of IOGOOS

The activities of IOGOOS, accordingly, would include the following:

3.1 Enhancement of ocean observing system

Identify gaps and deficiencies in the existing/planned ocean and coastal observing system (in situ and remote sensing) and develop a program for realizing a well-designed ocean observation system for the region, adhering to the GOOS principles

Promote the development of low-cost and efficient instrumentation and observing systems

3.2 Data Management, Data Exchange and Communication

In accordance with the GOOS principles on data:

i. Promote the development of low-cost and efficient systems for acquisition, management, processing and interpretation of data

ii. Expand and strengthen networking of countries using modern technology including internet for real- and near-real-time exchange of data and products

iii. Promote the development of standardized operational data procedures, including data quality control and data management

iv. Provide high-quality data and time-series for a better understanding and improved management of the Indian Ocean ecosystem

v. Collaborate with other programs and bodies in the field of data collection and data management

vi. Coordinate GOOS data acquisition with existing regional and national data gathering systems under the agreements and conventions (e.g., relating to pollution monitoring, marine meteorology, navigation and safety at sea etc.), and

vii. Publish findings of meetings, workshops, studies and other documents commissioned by the IOGOOS Members, submit documents to international meetings related to GOOS, and assure collective representation of GOOS to regional and national agencies/institutions/authorities when requested by Members.

3.3 Ocean services

i. Identify priorities for operational oceanography and ocean services in the Indian Ocean region, based on evaluation of social and economic benefits

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ii. Promote the development of regional and local operational oceanography, taking into account the components of GOOS, for realizing services and products of maximum value to the countries of the region

iii. Support operational oceanography and services in collaboration with marine-related public and private sector organizations and programs

3.4 Capacity-building

i. Identify the training needs of countries in the region and promote organization of training courses, workshops and seminars

ii. Promote the development of common infrastructure, major systems or capital installations required to support operational oceanography in Indian Ocean

iii. Promote and aid capacity-building, exchange of know-how, technology and personnel, as well as collaboration, within the framework of GOOS

iv. Promote pilot projects and studies in the countries of the region to demonstrate the economic benefits of GOOS, and

v. Strengthen collaboration with GOOS and JCOMM capacity-building panels and IOC/TEMA including IOCINWIO and IOCINDIO capacity-building programs.

3.5 Research

Promote research and pre-operational research for solving problems relating to operational oceanography in the Indian Ocean.

3.6 Cooperation with other programs and bodies

i. Contribute to international planning and implementation of GOOS

ii. Assist in developing policies for the furtherance of GOOS and coordinate the best regional participation in GOOS, identifying where greatest value is added by collaboration

iii. Promote collaboration between existing regional multi-national agencies/institutions/authorities, programs, organizations, and initiatives having expertise in oceanography, operational systems, and remote sensing of the ocean

iv. Collaborate, as appropriate, with GOOS-Africa, NEAR-GOOS, SEA-GOOS, WAGOOS and WIOMAP through joint projects and activities

v. Cooperate, as appropriate, with organizations concerned with the assessment of climate change, global environmental research, and the impacts of climate variability and climate change

vi. Promote collaboration with space agencies/institutions/authorities and remote-sensing scientists and engineers so as to ensure optimum integration of both in situ and remote-sensing data in operational oceanography

vii. Promote collaboration between institutes and agencies in providing/attracting aid and assistance to developing countries for operational oceanography, and the necessary capacity-building, and

viii. Provide as appropriate, expertise, consultants, etc., to the GOOS Steering Committee (GSC), IOC–WMO–UNEP Committee for GOOS (I-GOOS), and to the international sponsoring agencies/institutions/authorities of GOOS.

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Article 4: Membership

4.1 IOGOOS Members will be national organizations (authorities, agencies, institutes) from the region who are willing to advance GOOS in their country and actively contribute to its extension in the Indian Ocean region.

4.2 Each Member will nominate one representative to participate in the Annual Meeting or a General Meeting of IOGOOS.

4.3 Multi-national organizations of the Indian Ocean region and agencies or institutes from outside the Indian Ocean region with an interest in Indian Ocean operational oceanography or research may be admitted as Associate Members of the Alliance at its discretion. Associate Members of IOGOOS will not have the right to vote at Annual and General Meetings but shall have all other rights, privileges and obligations as given to Members, including the payment of an annual subscription.

4.4 The signatories to this MoU have been admitted as the initial Members of IOGOOS.

4.5 Admission of a new Member to IOGOOS shall be done by the Annual Meeting, based on written application made to the Secretariat of IOGOOS. Such application shall be made by the Head of the agency/institution/authority and seconded by at least two Members.

4.6 When any agency/institution/authority from a country wishes to join IOGOOS and there is already one or more Member(s) from that country, the applicant shall include a written statement that the existing Member(s) agree(s) to the Membership of the new Member and that the agencies/institutions/authorities from the same country will work in collaboration.

4.7 A Member may withdraw from IOGOOS by giving at least six months notice to the Secretariat. Its departure takes effect on the 31st December of the year in which it notified its decision. A Member remains liable for its commitments made prior to the decision to leave unless agreed differently by the remaining Members acting unanimously.

4.8 In the event of a Member not meeting its obligations, financial or otherwise, an Annual Meeting acting by a two-thirds majority (not counting the concerned Member) may decide the exclude the Member and relieve it of the commitments made prior to the decision to expel.

Article 5: Annual Meetings and General Meeting

5.1 The Alliance shall, in each calendar year, hold an Annual Meeting in addition to any other general meetings in that year and shall specify the meeting as such in the notices calling it. The Alliance shall hold its first Annual Meeting within fifteen months of this MoU entering into force. Not more than fifteen months shall elapse between the date of one Annual Meeting of the Alliance and that of the next. The Annual Meeting shall be held at such time and place as decided by the Officers at the previous meeting.

5.2 Major items of policy shall be discussed and decided at the Annual Meeting, including the establishment of projects, formation of subsidiary bodies, review of work, and modification of the Rules, with instructions and guidance for the Officers for the coming year. The Secretariat will provide an agenda to all Members, approved by the Officers, at least two months before the meeting.

5.3 The Annual Meeting shall receive reports from the Chairperson of IOGOOS and the Chairpersons of the principal subsidiary bodies. The accounts and financial summary for the previous year and the budget for the following year shall be submitted for approval.

5.4 The subscription required from Members shall be fixed by the Annual Meeting from time to time.

5.5 Appointment of Officers and recognition of new Members shall be made at Annual Meetings.

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Article 6: Officers

6.1 The Members at the Annual Meeting will appoint the Chairperson and four Officers providing a balanced representation of the region.

6.2 The Chairperson and Officers will serve for two years and be responsible for all IOGOOS activities between Annual Meetings. They will be eligible for re-appointment for up to a maximum of two successive terms.

6.3 The Chairperson and the Officers will select a Secretary who will be responsible for ensuring the satisfactory implementation of all decisions made by the Annual Meeting and between Annual Meetings by the Officers, for the IOGOOS Office and for the management of IOGOOS funds. The Secretary will report to the Chairperson and to the Officers. He/she will prepare papers for the Annual and other meetings and may represent IOGOOS at international organizations as required by the Officers.

6.4 The Officers may exercise the powers of the Alliance in accordance with this MoU and the policies and directions agreed by the Members at the Annual Meeting from time to time. Any acts or decisions of the Officers not so authorized in advance shall be subjected to the approval of the Members at the next Annual Meeting following such act or decision.

6.5 The Head of IOC Regional Programme Office in Perth, as well as the Chairpersons of IOCINCWIO and IOCINDIO, will be invited to attend the IOGOOS Officers' meetings.

6.6 The Chairperson or an Officer may give notice one year in advance of his/her intention to retire and in that case the following Annual Meeting shall appoint a replacement.

6.7 The Alliance may by ordinary resolution appoint a person who is willing to act as an Officer either to fill a vacancy or as an additional Officer and may also determine the rotation in which any additional Officers are to retire.

Article 7: IOGOOS Secretariat

7.1 The IOGOOS Secretariat will be established at a leading oceanographic research establishment in the Indian Ocean region. The Secretary and staff will be based at the Secretariat. The cost of running of IOGOOS Secretariat, i.e., providing accommodation, support services, and/or professional staff, shall be met by the host agency/institution/authority. Members may second additional staff to the IOGOOS Secretariat. The functioning of the Office will follow the practices of the host agency/institution/authority.

7.2 The location of the Office may be rotated after six years from one Member to another by agreement of Members at an Annual Meeting at least one year in advance of the date of transfer.

7.3 Members will be requested to submit proposals to host the Secretariat. The host institution for the Secretariat will be decided at the first Annual Meeting.

Article 8: Subsidiary Bodies and Projects

8.1 The Members at an Annual Meeting or the Officers between Annual Meetings acting within the powers defined in Article 6, may create or abolish any committee, working group, project team or task team consisting of one or more Officers or other nominated representatives of Members. Representatives of agencies/institutions/authorities not being Members may be invited to join any committee, working group, project or task team with the approval of the Officers. Any such committee, working group, project, or task team may be made subject to any terms of reference the Officers may impose in accordance with the Rules.

8.2 The Officers may appoint any person as an Associate Officer who may represent any committee, working group or task team at meetings of the Officers for the purpose of liaising with and reporting the actions of such committees to the Officers. The Associate Officers shall not by virtue of their appointment as such be Officers of the Alliance and they shall not have a right to attend and vote at the meetings of Officers.

Article 9: Rules of Procedure

9.1 The Alliance may from time to time make such Rules as it shall deem necessary, expedient or convenient for the proper conduct and management of the Alliance and for the purposes of prescribing conditions of Members.

9.2 The Alliance, in its general meeting, shall have the power to alter, add to or repeal the Rules. The Secretariat shall circulate any such information to all Members.

Article 10: Decision-making at Annual and General Meetings

10.1 All issues raised at any meeting of the Alliance shall, if possible, be decided with the unanimous consent of all Members present at such meeting and all Members shall use their respective reasonable endeavors to reach consensus in relation to all issues at each meeting. If any matter relating to the affairs of the Alliance has been considered by a meeting of the Members and no decision or resolution has been arrived at at the meeting in relation to the matter by reason of the non-unanimous consent of all Members present, then the matter shall be carried over to a further meeting of Members to be held within three months of the date of the meeting at which the matter was first raised (the Adjourned Meeting).

10.2 Pending the Adjourned Meeting the Members shall continue to use their reasonable endeavors to liaise with each other to obtain a common consensus with a view to agreeing the matter to be decided at the Adjourned Meeting.

10.3 If, at an Adjourned Meeting and following an appropriate period of debate, a matter cannot be agreed upon by all Members present and voting then the matter shall be decided by a majority of 75% of those Members present and voting.

10.4 Each Member has the right to appoint an authorized representative to attend Annual Meetings and has the right to vote.

10.5 An instrument appointing a duly authorized representative shall be in writing, executed by or on behalf of the appointing Member. The Secretariat will keep an up to date list of all representatives which will be made available to any Member on request.

Article 11: Management of Subsidiary Bodies

11.1 Subsidiary bodies of IOGOOS created in accordance with Article 8 shall be established with written terms of reference and outline work tasks, which shall be confirmed or altered at regular intervals specified in their Terms of Reference. The number of standing bodies or committees shall be kept to a minimum. Subsidiary bodies or panels should be created for a specific task and disbanded after a fixed time.

11.2 Subsidiary bodies of IOGOOS shall report to the Annual Meeting with a summary of their achievements, meetings held and forthcoming plans, if any.

11.3 When a subsidiary body deems it necessary to create a further subsidiary or panel this shall only be done with agreement of the Officers, and the status and terms of reference of the new body shall be submitted to the next Annual Meeting for approval or disbanding.

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11.4 Subsidiary bodies may initiate projects and set up project-organizing groups seeking grants to fund projects. In all cases where projects are considered or planned, the subsidiary body shall seek approval from the Officers, and inform the IOGOOS Secretariat.

11.5 The leaders of all Subsidiary bodies and projects shall meet collectively from time to time under the Chairpersonship of an Officer to review the range of work and projects being undertaken by IOGOOS. This meeting shall usually be conducted in conjunction with the Annual Meeting.

Article 12: Funding IOGOOS

12.1 The primary source of funding for IOGOOS will be through annual subscriptions from Members and voluntary contributions from Members, GOOS or its sponsors to an "IOGOOS Central Fund" that will be used to support activities and operations of IOGOOS such as hosting meetings, organizing workshops, ad hoc study groups or pilot projects, hosting of Websites, consulting services to national and multilateral bodies, employing consultants, financing publications, providing for their own costs of communications, and other items as agreed upon by Members at the Annual Meeting.

12.2 The Annual Subscription is fixed, initially, as USD 500 (five hundred) per Member. The Annual Meeting shall revise the annual subscription, as necessary.

12.3 IOGOOS may solicit in-kind contributions from Members, including seconding of Officials to support operations and activities of IOGOOS as well as contribution to the funds of the Alliance in the shape of donations, subscriptions, grants, funds from other agencies.

12.4 Members and other participants shall mobilise subvention on their own, to cover the costs of attending meetings of IOGOOS.

Article 13: Financial Management

13.1 Financial transactions of IOGOOS shall be conducted through the financial services office of the host agency according to its standard practices.

13.2 In Accordance with Article 5.3 the Secretary shall present a report of the financial state of the Alliance to the Annual Meeting. The report shall be approved by the Officers prior to distribution and shall be scrutinized in particular by one Officer appointed for the task.

13.3 The Alliance shall have the following powers exercisable in furtherance of its aims, objectives and activities but not otherwise, viz.

i. To issue appeals, hold public meetings and take such other steps as may be required for the purpose of procuring contributions to the funds of the Alliance in the shape of donations, subscriptions, grants, funds from other agencies

ii. To engage and pay any person or persons whether on a full-time or part-time basis or whether as consultant or employee to supervise, organize, carry on the work of and advise the Alliance. The income and property utilized by the Alliance shall be applied solely to the promotion of its objectives as set forth in this MoU and no portion thereof shall be paid or transferred directly or indirectly by way of dividend, bonus or otherwise by way of profit, to Members of the Alliance and no Officer of the Alliance shall be appointed to any office of the Alliance paid by salary or fees or receive any remunerations or other benefit in money or money's worth from the Alliance.

Article 14: Collaboration with Other Organizations

14.1 In accordance with the objectives of the Alliance set out in Article 3, IOGOOS will work closely with other organizations to promote operational oceanography.

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14.2 The Annual Meeting may invite representatives of other organizations to establish a link with the Alliance or may arrange exchange of observers or cross-membership, in accordance with classes of Membership.

14.3 The Alliance is a regional subsidiary of the Global Ocean Observing System (GOOS) and as such, will seek to develop GOOS objectives in the Indian Ocean region in collaboration with the governing body of GOOS, and in collaboration with other regional GOOS organizations.

Article 15: Duration

IOGOOS will continue until such time as an Annual Meeting of Members decides that it should end.

Signatories to the IOGOOS Agreement

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