Intergovernmental Oceanographic Commission

Workshop Report No. 67

# Interdisciplinary Seminar on Research Problems in the IOCARIBE Region

Caracas, Venezuela, 28 November - 1 December 1989

Unesco

# IOC Workshop Reports

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| No. | Title | Publishing Body | Languages |
|---|---|---|---|
| 1 | CCOP-IOC, 1974, Metallogenesis, Hydrocarbons and Tectonic Patterns in Eastern Asia (Report of the IDOE Workshop on), Bangkok, Thailand 24-29 September 1973 UNDP (CCOP), 138 pp | Office of the Project Manager UNDP/CCOP c/o ESCAP Sala Santitham Bangkok 2, Thailand | English |
| 2 | CICAR Ichthyoplankton Workshop, Mexico City, 16-27 July 1974 (Unesco Technical Paper in Marine Sciences, No 20). | Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) Spanish (out of stock) |
| 3 | Report of the IOC/GFCM/ICSEM International Workshop on Marine Pollution in the Mediterranean, Monte Carlo, 9-14 September 1974. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish (out of stock) |
| 4 | Report of the Workshop on the Phenomenon known as "El Niño", Guayaquil, Ecuador, 4-12 December 1974. | FAO Via delle Terme di Caracalla 00100 Rome, Italy | English (out of stock) Spanish (out of stock) |
| 5 | IDOE International Workshop on Marine Geology and Geophysics of the Caribbean Region and its Resources, Kingston, Jamaica, 17-22 February 1975. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) Spanish |
| 6 | Report of the CCOP/SOPAC-IOC IDOE International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Suva, Fiji, 1-6 September 1975. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 7 | Report of the Scientific Workshop to Initiate Planning for a Co-operative Investigation in the North and Central Western Indian Ocean, organized within the IDOE under the sponsorship of IOC/FAO (IOFC)/Unesco/EAC, Nairobi, Kenya, 25 March-2 April 1976. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish Russian |
| 8 | Joint IOC/FAO (IPFC)/UNEP International Workshop on Marine Pollution in East Asian Waters, Penang, 7-13 April 1976. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) |
| 9 | IOC/CMG/SCOR Second International Workshop on Marine Geoscience, Mauritius, 9-13 August 1976. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish Russian |
| 10 | IOC/WMO Second Workshop on Marine Pollution (Petroleum) Monitoring, Monaco, 14-18 June 1976. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish (out of stock) Russian |
| 11 | Report of the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain Trinidad, 13-17 December 1976. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English Spanish (out of stock) |
| 11 Suppl. | Collected contributions of invited lecturers and authors to the IOC/FAO/UNEP International Workshop on Marine Pollution in the Caribbean and Adjacent Regions, Port of Spain, Trinidad, 13-17 December 1976. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English Spanish |
| 12 | Report of the IOCARIBE Interdisciplinary Workshop on Scientific Programmes in Support of Fisheries Projects, Fort-de-France, Martinique 26 November-2 December 1977. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish |
| 13 | Report of the IOCARIBE Workshop on Environmental Geology of the Caribbean Coastal Area, Port of Spain, Trinidad, 16-18 January 1978. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English Spanish |
| 14 | IOC/FAO/WHO/UNEP International Workshop on Marine Pollution in the Gulf of Guinea and Adjacent Areas, Abidjan, Ivory Coast, 2-9 May 1978 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French |
| 15 | CPPS/FAO/IOC/UNEP International Workshop on Marine Pollution in the South-East Pacific, Santiago de Chile, 6-10 November 1978 | IOC Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) |
| 16 | Workshop on the Western Pacific, Tokyo 19-20 February 1979 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Russian |
| 17 | Joint IOC/WMO Workshop on Oceanographic Products and the IGOSS Data Processing and Services System (IDPSS), Moscow, 9-11 April 1979. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 17 Suppl. | Papers submitted to the Joint IOC/WMO Seminar on Oceanographic Products and the IGOSS Data Processing and Services System, Moscow, 2-6 April 1979. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 18 | IOC/Unesco Workshop on Syllabus for Training Marine Technicians, Miami, 22-26 May 1978 (Unesco reports in marine sciences, No 4) | Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) French Spanish (out of stock) Russian |
| 19 | IOC Workshop on Marine Science Syllabus for Secondary Schools, Llantwit Major, Wales, U.K., 5-9 June 1978 (Unesco reports in marine sciences, No. 5). | Division of Marine Sciences, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish Russian Arabic |
| 20 | Second CCOP-IOC Workshop on IDOE Studies of East Asia Tectonics and Resources, Bandung, Indonesia, 17-21 October 1978 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 21 | Second IDOE Symposium on Turbulence in the Ocean, Liège, Belgium, 7-18 May 1979. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish Russian |
| 22 | Third IOC/WMO Workshop on Marine Pollution Monitoring, New Delhi, 11-15 February 1980. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish Russian |
| 23 | WESTPAC Workshop on the Marine Geology and Geophysics of the North-West Pacific, Tokyo, 27-31 March 1980. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English Russian |
| 24 | WESTPAC Workshop on Coastal Transport of Pollutants, Tokyo, 27-31 March 1980. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) |
| 25 | Workshop on the Intercalibration of Sampling Procedures of the IOC/WMO UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open-Ocean Waters, Bermuda, 11-26 January 1980. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English (superseded by IOC Technical Series No. 22) |
| 26 | IOC Workshop on Coastal Area Management in the Caribbean Region, Mexico City, 24 September-5 October 1979. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English Spanish |
| 27 | CCOP/SOPAC-IOC Second International Workshop on Geology, Mineral Resources and Geophysics of the South Pacific, Nouméa, New Caledonia, 9-15 October 1980. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 28 | FAO/IOC Workshop on the effects of environmental variation on the survival of larval pelagic fishes Lima, 20 April-5 May 1980. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 29 | WESTPAC Workshop on Marine biological methodology Tokyo, 9-14 February 1981. | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 30 | International Workshop on Marine Pollution in the South-West Atlantic Montevideo, 10-14 November 1980. | IOC, Unesco Place de Fontenoy, 75700 Paris, France | English (out of stock) Spanish |
| 31 | Third International Workshop on Marine Geoscience Heidelberg, 19-24 July 1982 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish |
| 32 | UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the context of the New Ocean Regime Paris, 27 September - 1 October 1982 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish |
| 32 Suppl | Papers submitted to the UNU/IOC/Unesco Workshop on International Co-operation in the Development of Marine Science and the Transfer of Technology in the Context of the New Ocean Regime Paris, 27 September-1 October 1982 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |

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SC-90/WS-57

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**FOREWORD**

The Interdisciplinary Seminar on Research Problems in the IOCARIBE Region, preceded the Third Session of the Sub-Commission held in Caracas, 4-8 December 1989. The two project proposals developed during the Seminar represent actions following previous preparatory steps organized by IOCARIBE. The project proposal on Climate Changes Impacts and Ocean Physical Processes derived maily out of recommendations of the IOCARIBE Workshop on Physical Oceanography and Climate (IOC Workshop Report No. 45). The project proposal on Impacts of Sea-Level Changes on the Coastal Zone - Effects on Erosion and Sedimentation evolved from elements of the IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN(OETB) Programme on Ocean Science in Relation to Non-Living Resources (IOC Workshop Report No. 48) and the Course on Knowledge and Management of the Coastal Zone in the Caribbean Region (IOC/INF-782). The full text of the scientific presentations of the Seminar will be published separately by the Institut de Géologie du Bassin d'Aquitaine (IGBA), 351, Cours de la Libération, 33405 Talence, France. The project proposals developed have been incorporated in the IOCARIBE Medium-Term Plan (1990-1995).

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**ANNEXES**

## 1. OPENING

The Interdisciplinary Seminar on Research Problems in the IOCARIBE region, was opened by Dr. Enrique Colmenares Finol, Ministro del Ambiente y de los Recursos Naturales Renovables, Venezuela, at 10.15, 28 November 1989, Parque Central, Caracas, Venezuela.

Dr. Colmenares welcomed the invited experts and briefly described the history and present situation of marine sciences in Venezuela and their relationship with IOC and UNEP activities.

Dr. Fernando L.E. Robles, IOC Senior Assistant Secretary for IOCARIBE, reviewed the administrative arrangements for the meeting and recalled the objectives of the Seminar as follows:

(i) To review through presentations given by scientists attending, the state of knowledge on research in the three following main interdisciplinary topics: a) Physical oceanography, including impacts of climate changes and associated hydrodynamics processes in coastal and shelf areas; b) Coastal sedimentation mechanisms and erosion problems; and c) Dispersion of contaminants/pollutants in certain key areas of the region.

(ii) As a synthesis of research papers and experiences presented, finalize an interdisciplinary regional project proposal relevant to the topics mentioned above.

The Programme of the Seminar is given in Annex I.

The List of Participants is provided in Annex II.

A List of Acronyms and Abbreviations is enclosed in Annex IV.

## 2. INTRODUCTORY PRESENTATION

Dr. Hernán Pérez-Nieto, President, Comisión Nacional de Oceanología (CNO) of Venezuela, introduced the presentation entitled "Territorial Organization of Marine and Coastal Areas in Venezuela". The presentation covered a period of about 25 years of observations regarding environmental problems in coastal and insular marine territories of Venezuela. An abstract of Dr. Pérez-Nieto's lecture is given in Annex III.

## 3. DESIGNATION OF CHAIRMAN, VICE-CHAIRMAN AND RAPPORTEUR

After consultations with the participants, Dr. Hernan Perez Nieto was proposed as Chairman, Dr. George Maul as Vice- Chairman and Mr. Bengt Axelsson as Rapporteur for the Seminar. These proposals were unanimously approved by the Seminar.

## 4. SCIENTIFIC PRESENTATIONS

The afternoon of 28 November and the 29 November were spent on papers introduced by the invited experts. Abstracts of these presentations are given in Annex III.

The following papers were presented:

| | |
|---|---|
| Mr. Julián Castañeda, Mr. Mario Capaldo and Dr. Otto Chourio | Physical Oceanography and Climate Variability in the Coastal Margin of Venezuela: State of Affairs and Projects. (Abstract not available) |
| Dr. José L. Juanes and Dr. Guillermo García | Coastal Stability, Erosion and Sedimentation: the case of Cuba |
| Dr. Jorge Corredor | Mechanisms of eutrophication and examples from Puerto Rico |
| Dr. George A. Maul | Physical oceanography and Climate in the wider Caribbean including impacts of climate changes and associate processes in the Coastal and Shelf Areas |
| Mr. Kenneth Atherley | Beach Recovery after Breakwater Modification on the West Coast of Barbados |
| Dr. George A. Maul | Regional Component of the Global Sea-Level Observing (GLOSS) Network |
| Dr. Raúl Mederos | Models of Dispersion of Contaminants (Abstract not available) |
| Dr. Frank Müller-Karger | Rivers in the Sea; Space-Based Observations of Ocean Colour in the Wider Caribbean Region |
| Dr. Maximiliano Bezada, Dr. Carlos Suárez Dr. Pedro Roa | Geomorphological Characterization of the Venezuelan Coasts with emphasis in and Erosion and Sedimentagion Areas |
| Dr. Kim G. Robertson | Delta Geomorphology along the Colombian Caribbean |
| Dr. Georges Vernette | Geomorphological and Sedimentary Characteristics in the Shelf and Coastal Areas in the Wider Caribbean Region |
| Prof. Gilberto Cedeño and Dr. Darío Bermúdez | Marine-Coastal Contamination. Perspectives in Venezuela |
| Dr. Jorge Corredor | Distribution of Petroleum Pollution - The CARIPOL Programme |
| Dr. Christian Colin | Western Boundary Currents as observed in Boreal Summer 1989 |

Dr. Georges Vernette, Institut de Géologie du Bassin d'Aquitaine, Université de Bordeaux, stated that France, through the IGBA, intends to publish the papers presented during the Interdisciplinary Seminar. Texts, of about ten to twenty pages (including figures and references) for each presentation, would be published in the original language, with abstracts in English, Spanish and French. The publication is scheduled for late 1990, provided that texts are submitted to Dr. Georges Vernette by the end of February 1990. Financial support from IOC is sought for this publication.

## 5. PROJECT PROPOSALS - PREPARATION AND DESCRIPTION

It was agreed that the participants should split into two Working Groups to develop the project proposal(s). The first group, under the co-ordination of Dr. George Maul, elaborated the proposal on Climate Changes Impacts and Ocean Physical Processes and the second, co-ordinated by Dr. Georges Vernette, contributed the proposal on Impacts of Sea-Level Changes on the Coastal Zone - Effects on Erosion and Sedimentation.

The Seminar acknowledged the particular relevance of these aspects from a scientific point of view. Likewise, it was considered pertinent to urge governments of IOCARIBE Member States to elaborate and implement, through the appropriate agencies, the necessary plans for the regulation and management of the territory and its natural resources, both renewable and non-renewable.

The Seminar, taking note of the level of development of the Project Proposal on Climatic Changes Impacts and Ocean Physical Processes recommended the IOC Sub-Commission for the Caribbean and Adjacent Regions to endorse the proposal at its Third Session in Caracas, Venezuela, 4-8 December 1989. It also requested the Secretariats of IOCARIBE and IOC to make the necessary arrangements to submit the proposal to IOC, Unesco and UNEP to be considered for immediate implementation.

### 5.1 CLIMATE CHANGES IMPACTS AND OCEAN PHYSICAL PROCESSES

The Working Group to further develop the Project Proposal on Climate Changes Impacts and Ocean Physical Processes was composed by : Dr. George A. Maul (NOAA, USA); Dr. Christian Colin (ORSTOM, France); TN Mario Capaldo (DHN, Venezuela); Dr. Gaspar González-Sanson (CON, Cuba); Lic. Guillermo García (CON, Cuba); Dr. Frank Müller-Karger (USF/MSL, USA); Dr. Jorge Corredor (UPR), Dr. Otto Chourio (DCN, Venezuela); MSc Julián Castañeda (IOV-UDO, Venezuela); Mr. Anders Alm (IOCARIBE) and Ms. Alessandra Vanzella (IOC).

The work of the group is presented below in the form of a project proposal.

#### 5.1.1 Project Identification

5.1.1.1 Title of project: Climate Change Impacts and Ocean Physical Processes.

5.1.1.2 Project number:

5.1.1.3 Subject Area:

5.1.1.4 Geographical Scope: (a) Region: 50 Latin America and the Caribbean

(b) Sub-region: 17 Action Plan for the Caribbean Environment Programme

5.1.1.5 Implementation:

(a) Co-operating Agency: The Intergovernmental Oceanographic Commission for (IOC) of Unesco through its Sub-Commission for the Caribbean and Adjacent Regions (IOCARIBE)

(b) NOAA - US Department of Commerce

(c) UNAM, Mexico City

(d) CIOH, Cartagena, Colombia

(e) CNO, Caracas, Venezuela

(f) CON, La Habana, Cuba

(g) University of South Florida

(h) University of Puerto Rico, Dept. of Marine Sciences

(i) ORSTOM, France

(j) USNO, Miami

(k) RSMAS, University of Miami

(l) Research Triangle Institute

(m) NORDA

5.1.1.6 Duration of Project: Five years
Commencing: 1990
Completion: 1995

**5.1.2 Background and Legislative Authority**

5.1.2.1 Background

The proposal is to conduct a study of the ocean physical processes of the waters in the environs of the semi-enclosed sea of the tropical and subtropical western North Atlantic Ocean. An understanding of these ocean physical processes is central to UN sponsored programmes such as Ocean Sciences in Relation to Living Resources (OSLR), Implications of Climatic Changes in the Wider Caribbean Region (ICCWCR), Marine Pollution Assessment and Control Programme for the Wider Caribbean (CEP-POL), Ocean Sciences in relation to Non-Living Resources (OSNRL), and Climate and Global Changes (C & GC) investigations of the WMO, ICSU, and WCRP. The proposal describes an effort of investigation including historical data analysis from the colonial records, in situ observations, education, satellite and site-specific monitoring, and numerical modelling, to further understanding of the physical processes that form the offshore boundary conditions for local coastal problems, for predicting the fate of pollutants including those from point sources such as rivers, and for contribution to furthered understanding of the ocean's role in climate and global change.

5.1.2.1.1 Introduction

One of the major issues facing mankind today is the prospect of global warming related to the green-house effect. Measurements of atmospheric parameters have been obtained over a long period of time on global scale and various predictive models have been established by the meteorological scientific community, but as yet there are few clear conclusions to be drawn from the model predictions, other than a consensus that temperature will rise. Much of the uncertainty of the model is based on the lack of understanding of the role of the oceans in the control of the climate. Therefore, much of the attention of the relevant scientific community is now directed towards studies of the oceans in programmes such as the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Studies (JGOFS). The aim of these programmes is to increase understanding and provide an extensive data base for modelling the ocean processes on a global scale. Eventually such models must be coupled to models of the atmosphere.

Nutrients inputs, both naturally and anthropogenically induced, by enhancing primary productivity increase the uptake of inorganic carbon that affects ocean/atmosphere CO2 exchange. The problem of atmospheric CO2 increase is thus intimately associated with biological productivity. Quantification of ocean productivity rates, especially in areas of high productivity such as upwelling ecosystems is consequently central to our understanding of the processes of ocean/atmosphere CO2 exchange.

The interest in the studies of climatic changes and the oceans is not only because of the need to improve the predictive power of atmospheric models; there is also considerable concern about the possible effect of climatic changes on the oceans themselves. An international debate has concentrated on the prospects of significant increase in sea-level, which might have serious repercussions for the very large part of humanity living in coastal settlements. Although there is now agreement in the scientific community that the rapid sea-level increases pictured a few years ago are unlikely, there is still a considerable degree of uncertainty about the possible fate of the polar ice-caps: will they melt because of global warming or will they, in fact, increase on a global scale, the IOC's GLOSS programme provides a remarkable example of international co-operation. One of the most important roles of intergovernmental agencies, such as the IOC, is to ensure the systematic collection, archiving and dissemination of global data. Sea-level data are collected by many countries. Some data are available in real-time, so that charts of sea-level anomalies can be calculated and disseminated. The monthly mean sea-level data are archived on a global scale, and the IOC's GLOSS programme provides a remarkable example of international co-operation. One of the most important roles of intergovernmental agencies, such as the IOC, is to ensure the systematic collection, archiving and dissemination of global data. Sea-level data are collected by many countries. Some data are available in real-time, so that charts of sea-level anomalies can be calculated and disseminated. The monthly mean sea-level data are archived by the IAPSO-ICSU Permanent Service for Mean Sea-Level.

It is customary to talk about global change in the context of climatic changes, but we witness today global changes in the ocean systems, particularly in the coastal zone, and also from pollution and various practices related to economic development. Pollution problems have been thought of as local, but there is evidence today that marine pollution is indeed transboundary. Furthermore, we see changes in coastal ecosystems

which have a similar pattern around the world. Nutrient enrichment in confined waters can lead to a change in the species composition of communities which may affect the economic use of the resources, but also to harmful algal blooms or "red tides" which are now occurring on a worldwide scale. Again there are likely feedbacks between the greenhouse effect and eutrophication/pollution of the sea.

Some problems and hazards are global in threat and extent, such as the general rise in sea-level which will occur if the greenhouse effect continues to warm the earth. Shelf sea transports and shelf break exchanges of important material may require multinational/regional efforts. Contamination studies in the Mediterranean, the Baltic and the North Sea provide clear regional examples. Organic carbon, of central and critical importance to the problem of climate change, requires a global perspective. The coastal and shelf seas, which link the continents to the world ocean require a fully international globally conceptual approach as we move into the decades of whole-earth science.

If we assume that we are able to make reasonable predictions about future climatic changes with acceptable confidence intervals, the next question is: what can we do about it? The obvious answer is in the reduction of greenhouse gas emissions, but even if the right and necessary political decisions were made today, there is a considerable time-lag in the natural systems which will delay the effects. This means that the world community must develop a strategy for adjustment to the climatic changes, which requires complex institutional arrangements. Governments have to act even before the scientific questions have been answered.

5.1.2.1.2 Earlier activities in the Caribbean and Adjacent Regions

The portion of the tropical and subtropical western North Atlantic Ocean called the Caribbean Sea and Adjacent Regions (CSAR) includes the Gulf of Mexico, the Caribbean Sea, the Bahamas, and the northeast coast of South America. The designation CSAR is an acronym of the Intergovernmental Oceanographic Commission (IOC) of Unesco; the term Wider Caribbean Region is used by the United Nations Environment Programme (UNEP) to define the same area. Although this proposal is to support approved programmes of both the IOC and UNEP, the term CSAR will be used because the regional programme in physical oceanography and climate was initiated at a meeting of the IOC's Sub-Commission for the Caribbean and Adjacent Regions (IOCARIBE) in 1986.

At the IOCARIBE Workshop on Physical Oceanography and Climate (Cartagena, Colombia, 19-22 August 1986) the basis of the CSAR programme was established, pointing out that circulation and sea-level is a unifying need to forecast future climate changes, erosion, and distribution of marine pollutants in the Caribbean and Adjacent Regions. Several steps were taken as a result of that meeting which led to the final approval by the IOC Executive Council in March 1988.

The IOCARIBE component of the GIPME-MARPOLMON Programme has for more than 10 years, carried out a successful regional marine pollution monitoring programme, including an extensive training component and development of a regional network of scientific laboratories and an efficient data handling system. A new phase for a better knowledge of the pollution situation will be initiated with the implementation of the joint IOC/UNEP Programme for Marine Pollution Assessment and Control Programme for the Wider Caribbean (CEP POL). The experiences from earlier monitoring activities and the new Marine Pollution Programme in the Caribbean will be greatly facilitated by a better understanding of circulation and transport

processes.

In response to the concern expressed in certain regions about the possible impacts of sea-level and sea temperature changes, induced by expected climatic changes and, in particular, those related to man's activities on coastal zones and areas, UNEP has initiated the preparation of regional studies on these matters. Through consultations between UNEP-RCU/CEP and IOC/IOCARIBE, a Regional Task Team was established to prepare a report entitled "Implications of Climatic Changes in the Wider Caribbean Region".

While a large historical data base exists regarding nutrient availability, phytoplankton biomass and productivity in the region, this information has been gathered non-systematically with little regard to intercalibration or to concerted synoptic data gathering. The advent of satellite-borne sensors now provides attractive means of providing synoptic views of regional distribution of sea-surface temperature and to a lesser extent of phytoplankton biomass. Satellite measurements, however, entail a large degree of uncertainty and consequently require detailed ground-truth information for validation.

5.1.2.1.3 Outputs Up-to-Date

In the Caribbean Region various activities have been carried out by IOCARIBE towards an increased understanding of the oceanographic circulation, sea-level variation and coastal geomorphology processes. The IOCARIBE-CARIPOL Marine Pollution Research and Monitoring Programme, the UNEP-IOC Review of the State of Marine Pollution in the Wider Caribbean and other related works have identified areas particularly vulnerable to impacts of climatic changes such as sea-level rise, temperature increase, water quality variations, and distribution of pollutants.

The development of a regional component of the global sea-level monitoring programme (GLOSS) has been initiated. The programme will benefit from satellite data from ERS-1 planned to be launched in January 1991. The regional sea-level monitoring programme will continue to be a corner-stone in the monitoring of variables relevant to impacts of climatic and other environmental changes.

A proposal submitted to the European Space Agency entitled "Oceanic Circulation in the Caribbean Sea and Adjacent Regions: An Intergovernmental Oceanographic Commission Proposal to the European Space Agency for ERS-1 Science, Application, and Validation" was selected in hard competition with other project proposals. In order to keep this IOCARIBE proposal as part of the ERS-1 investigators plan, it is vital to have statements of funding commitments at least one year prior to launch date. A withdrawal of the IOCARIBE proposal from ERS-1 would be extremely negative for the possibilities to predict and forecast climatic and other environmental changes in the CSAR.

Activities related to or connected with impacts of the oceanic circulation in the CSAR, have resulted in the following outputs:

(i) The IOCARIBE Workshop on Physical Oceanography and Climate, Cartagena, Colombia, 19-22 August 1986.

(ii) The project proposal "Oceanic Circulation in the Caribbean Sea and Adjacent Regions: An Intergovernmental Oceanographic Commission Proposal to the European Space Agency for ERS-1 Science, Application, and Validation".

(iii) The English-Spanish Bibliography in Physical Oceanography and Ocean Climate for the Caribbean Sea and Adjacent Regions (IOC/INF-783 - 1988).

(iv) First UNEP-IOC Meeting on Implications of Climatic Changes in the Wider Caribbean Region, Kingston, Jamaica, 31 July - 1 August 1987.

(v) Second Meeting of the UNEP-IOC Task Team on Implications of Climatic Changes in the Wider Caribbean, Miami, USA, 2-4 March 1988.

(vi) "Implications of Climatic Changes in the Wider Caribbean Region", A Draft Report by the Task Team of Experts, Mexico City, 7-9 September 1988 (done jointly with UNEP/RCU).

Recognizing that the interest of many IOCARIBE Member States is primarily in the economic and applied aspects of shelf and coastal processes, it has been determined that a circulation project is basic and essential to the common good. All efforts in the IOC-sponsored physical oceanography of the CSAR are initially concentrated on the successful implementation and completion of a coastal (open sea) sea-level/weather monitoring network. It is also recognized that individual Member States have highly specialized needs which will be addressed through an IOC programme on Training, Education, and Mutual Assistance (TEMA).

5.1.2.1.4 Oceanography of the CSAR

The geography of the CSAR Basin is that of a semi-enclosed sea with numerous passages of varying sill depth for the inflow/outflow of its surface and deep waters. Meteorologically, the Caribbean Sea is characterized by variability in the Inter-Tropical Convergence Zone (ITCZ)/Trade Wind System, resulting in wind stress often in excess of 2 dynes/cm , and by variations in precipitation from 100 mm/year to 2000 mm/year along the South American coast. Sea-surface temperatures average 25-26°C in winter to 28-29°C in summer and have an annual cycle of 0.4°C at 100m depth sea-surface salinity averages 35-36% in winter to 33-36% in summer with evidence of both precipitation and runoff significantly affecting the variability.

Sill depth of most passages is less than 2000 m which effectively prevents North Atlantic Deep Water from entering the CSAR Basin. Temperatures below 2000 m in the Caribbean Sea are characterized by extremely small variability, resulting in a deep barotrophic fluid. T-S correlations are dominated by the 36.5% maximum at 0°C, which characterizes the Sub-tropical Under Water (SUW), and by the 34.9% minimum at 7°C, characteristic of Antarctic Intermediate Water (AIW). Geostrophic velocities in the SUW are typical of surface velocities because of depths in the SUW core are less than 200 m. Average geostrophic flow shows a broad westward-flowing Caribbean Current which is strongest in the Southern half of the basin, but forming into the intense Yucatan Current where surface speeds often exceed 200 cm/s. Most of the speeds are less than 20 cm/s below 1000 m depth.

The deep water of the Caribbean Sea is controlled by overflow from the Atlantic. In the southeastern Caribbean a geological feature known as the Cariaco Basin is one of the most unique features in the world. It has a shallow sill (200 m) that is ordinarily ventilated by water from the juxtaposed Venezuelan Basin. In recent years, geochemical evidence suggests

the ventilation has ceased, and this can be interpreted as being caused by a decrease in the strength of the Caribbean Current. This has profound global climatic implications because the Caribbean Current contributes very significantly to the oceanic flux of heat from the tropics to mid-latitudes where air-sea interaction is the primary mechanism of moderating North Atlantic climate.

Volume transport into the Caribbean Sea appears to vary annually, as far as the western equatorial warm waters and fresh waters associated with the Amazon river discharges are concerned. Following the northward displacement of the ITCZ in May-June, the Guyana Current, extension of the South Equatorial Current and the North Brazil Coastal Current, veers (retroflects) to the east instead of flowing along shore as observed during the first part of the year. The USA-France physical oceanographic programme underway will bring valuable data in order to quantify the impact of the retroflexion phenomenon on the seasonal variability of the mass and heat transports associated with the Guyana Current.

In all cases, flow into the Caribbean Sea comes mostly through the Grenada, St. Vincent and St. Lucia passages in the Lesser Antilles (about 20 x 10 m/s total), with the other 10 x 10 m/s of the total of 30 x 10 m/s, from the Windward Passage. There appears to be a great deal of uncertainty in the mean values, and current meter moorings have shown substantial evidence of deep counter flows in many passages. Further evidence of substantial variability is seen in Lagrangian Drifter tracks; the most notable variability is that of mesoscale eddies throughout the region. The flow, however, is dominated by a strong annual cycle which is in phase with the wind stress, and affects the Gulf Stream System from the central Caribbean Sea to the offing of Cape Hatteras (35ºN). Associated with the annual volume transport and current speed cycle is a substantial heat flux variability of greater than 0.25 x 10$\underline{15}$ Watts.

The Gulf of Mexico connects with the Caribbean Sea through the Yucatan Strait (sill depth 2000 m) and with the western north Atlantic via the Straits of Florida (sill depth 800 m). Flow in the Yucatan Strait is northward and is clearly that of a major western boundary current. The Yucatan Current surface speed is in phase with the Caribbean Current and can be reasonably observed by sea-level differences between Mexico and Cuba. Current direction in the Yucatan Strait below 1000 m is often observed to be towards the south as inferred by geostrophy, silicate distributions, and current meter observations.

Hydrographic reports of the Gulf of Mexico have been published since 1898; most of the early work relates the observed littoral drift to the offshore and deep circulation. It was not until 1935 that the first sound descriptions of the water masses and their motion within the Gulf started to emerge. The present day accepted picture of the regional oceanography of the Gulf follows:

(i) Waters below 1500 m are nearly uniform in the horizontal with an almost neutral vertical stability index. Temperature and salinity values range between 4.00 to 4.15ºC and 34.96% to 34.90% , respectively. Such values imply that their source is in the Cayman Sea Basin, which in turn is intermittently supplied with Deep Western North Atlantic Water through the Windward Passage where the sill depth, one of the deepest passages to the Caribbean Sea is close to 1600 m.

(ii) Waters above 1500 m are well stratified and approximately uniform in the horizontal. Remnant AIW occupies a 300 m thick layer

throughout the Gulf at an average depth of 700 m. This water mass shows as a salinity minimum which is clearly eroded from its entrance value, 34.86% at the Yucatan Strait, to a value of 34.89%. in the southwest Gulf. This suggests a longer residence time of this water mass in the southwest region.

(iii) The salinity core maximum (36.75% ) at an average depth of 150 m in the middle of the Yucatan Strait and a few tens of meters shallower or deeper within the Gulf, specifies the SUW, whose origin is traced to the surface salinity maximum in the North Atlantic (20-25ºN,30-50ºW). Compared to the values at the Yucatan Strait and Straits of Florida, the salinity maximum values in the southwestern Gulf are lower.

(iv) The description and understanding of the water masses and circulation in the surface layer of the Gulf is far from being completed. Nevertheless, sea-surface temperature and surface salinity help to demarcate: (a) seasonal variations, (b) river discharge effects, (c) intense local energy interchange events at the ocean-atmosphere interfaced) shelf and oceanic waters and (d) Loop Current waters from Gulf resident waters.

The historical mean dynamic topography of the Gulf and the space-time averages of surface and subsurface velocity measurements indicate that the circulation is dominated by the Loop Current in the central and eastern Gulf while the circulation in the west is driven equally by the curl of the wind stress and by the eddies that regularly separate from the Loop Current. This current is maintained by the Yucatan Current which imports surface and subsurface water into the Gulf at an average rate of 30 x 10 m /s. The flow continues into the central Gulf where it loops east and southward (thus its name) and exits through the Straits of Florida to continue along the east coast of the United States as the Florida Current.

A sequence of events, starting with the intensification of the wind over the Caribbean Sea, finally induces flow instabilities in the Yucatan and Loop Currents that force the generation and eventual separation of an eddy that moves slowly (2-5 km/day) to the west and dissipates against the shelf slope off Tamaulipas (Mexico) and Texas (USA). This situation repeats once every 10.9 months, as an average, and most recent research suggests that ring separation occurs most often in the winter, which is 180 out of phase with the time of maximum transport in that region. Typical scales of these anticyclonic eddies are 250-400 km in diameter, the same as the north-south length scale of the anticyclonic circulation usually observed in the central and northwestern Gulf.

Most of the water that enters the Gulf through the Yucatan Strait exits through the Straits of Florida. Calculations show that about 10% of the imported water stays in the Gulf, incorporated by intense mixing, while an equivalent volume of resident Gulf water is entrained in the eastern Gulf circulation and flows to the western north Atlantic. Monitoring of the volume transport in the Straits of Florida by submarine cable and by sea-level difference shows variations greater than 20% of the mean can occur in a fortnight.

Recently, a 3-year long time series of velocity measurements near sill depth in the Yucatan Strait clearly indicated a persistent southward flow, 2 cm/s on average with a few month-long bursts up to 10 cm/s. The observed outflow seems to contradict the historical T-S geographical variation from the Yucatan Strait to the south-western Gulf (erosion of salinity minimum). The topographical constraint imposed by the sill depth

difference between the Florida and Yucatan Straits (1200 m) is a controlling factor in the inflow-outflow condition through the Yucatan Strait. The observed outflow could be restricted to the thickness of the local boundary bottom layer, in which case this volume transport would not be significant considering the volume transport over the whole water column along the strait.

Energy budget studies of the CSAR show that there is a net import of thermal energy via ocean currents. The excess is given up to the atmosphere mostly in the form of latent heat (evaporation). Estimates of the water balance of the Gulf indicate that river runoff compensates the evaporation minus precipitation term. Since the Gulf is a net evaporation basin, this last term is positive. Any unbalance between net evaporation and river runoff is compensated accordingly by net volume inflow or outflow.

Analytical models have been developed and laboratory model experiments were carried out successfully and contributed in their time, to the understanding of the basic dynamics of the Gulf circulation. Nevertheless, increasing computer facilities concentrated and promoted the development of numerical models of the Gulf. Starting with single layer barotrophic models and progressing to multi-layer baroclinic models, simulation of the Gulf circulation has improved substantially. However, finer time-space resolution and more realistic boundary conditions should be used in order to assess the importance of mesoscale processes in the redistribution and dissipation of energy throughout the Gulf system.

Expansion of the numerical models to include the Caribbean Sea is rapidly evolving, and five models are prominent: Oxford University, Florida State University, Geophysical Fluid Dynamics Lab (NOAA), and two of different resolution at the Navy Ocean Research and Development Activity (NORDA). Model results show the need for higher spatial resolution with realistic bottom topography. Results from such calculations show realistic amplitude and phase for the annual transport signal, but do not resolve adequately the mesoscale eddies. Higher spatial resolution sub-regional scale models show a complicated pynocline height anomaly that is representative of westward advecting cyclonic/anticyclonic eddy pairs similar to those observed by Lagrangian Drifters. Future direction of modelling research, in addition to improved resolution, must be towards ingesting a variety of ship-of-opportunity, sea-level/weather, satellite, and other <u>in situ</u> data, so as to provide realistic simulations as offshore boundary conditions for island-scale models, and as input to global efforts by the oceanographic community.

The CSAR plays a fundamental role in the circulation of the North Atlantic Ocean. It is a region rich in temporal and spatial scales of variability in the motion of its waters, and is directly influenced by the runoff of the three largest rivers in North and South America. Complexity of near-surface oceanic phenomena is a nested hierarchy of Gulf Stream System formation and dissipation (eddy) dynamics; mesoscale and coastal scale upwelling; near-shore currents, waves, and transport including beach erosion; estuarine circulation; and sea-level variability from tidal to interannual scales.

Central to each of these nested problems is the need to know the basin scale upper layer circulation and inflow/outflow volume transport. Circulation on the continental and/or island shelves is strongly influenced by fluctuations of the deep water currents; similarly littoral circulation is strongly influenced by the shelf currents and winds. The physical understanding of coastal circulation dynamics is not possible without direct knowledge of the offshore variability, which provides the boundary

conditions necessary to any inshore modelling.

5.1.2.1.5 Data Availability

5.1.2.1.5.1 Satellite Data

5.1.2.1.5.1.1. ERS-1 Data

The ERS-1 satellite is the first European remote sensing satellite and falls under the jurisdiction of the European Space Agency (ESA). Our most recent information from ESA indicates that the launch date for ERS-1 is in early 1991. Among the goals of the ERS-1 satellite are to contribute knowledge of the oceans, coastal regions, and ice zones, and to contribute to climate research. In the realm of general oceanic problems, the aim of the ERS-1 is to provide data to study ocean circulation, eddy structure, wind/wave interaction, air/sea interaction, and sea-surface topography. In the realm of ice zone studies, ERS-1 will provide information for ice sheet and sea ice mapping and to study ice sheet and sea-ice dynamics. For climate research, ERS-1 will provide data for air/sea interaction studies, surface energy budget studies, and for studies on climate variability.

The payload of the ERS-1 consists of five remote sensing systems. These are: a scatterometer to obtain data on surface wind speed and direction; a synthetic aperture radar (SAR), for imaging land, ice, and the costal zone; a radar altimeter (RA) to provide data on sea-surface height, wind speed, and wave characteristics; a microwave radiometer to provide the distribution of water vapor which will be used to correct the altimeter data; and a scanning infrared radiometer to provide information on sea surface temperature. The systems of particular interest to this study are the scatterometer and the radar altimeter.

ERS-1 will be placed in a sun synchronous orbit with a height of approximately 750 to 800 km. The orbital configuration in which the ERS-1 will be initially placed will be such as to provide a 35-day repeat cycle. However, during the course of the lifetime of ERS-1, it is expected that other orbital configurations will be used. Other possible orbital configurations will yield a 3-day repeat cycle, 7-day repeat cycle, 11-day repeat cycle, a 20-day repeat cycle, and a 29-day repeat cycle.

For dynamic oceanography, the information of greatest interest is the RA range from the orbit to the surface. The difference between the height of the satellite above an ellipsoid of reference and the RA range is called the sea-surface height (SSH). The measured SSH is dominated by variations in the geoid (order 100 m), variation in dynamic height anomaly (order 2 m), solid earth and ocean tides (order 1 m), and the orbit error (order 1 m). The geoid is unknown at centimeter accuracy but is constant in space; tides are fairly well modelled and of long wave length in comparison to the dynamic height anomaly; orbit error is random but can be determined when ERS-1 is in an exact repeat (collinear) orbit.

The ERS-1 scatterometer will provide data along a 400- km wide swath located to the right of the subsatellite track looking downstream along that track. The first data point will be found 100 km to the right of the track and the last data point, 500 km to the right. The spatial resolution of the scatterometer system is 45 km (i.e. the diameter of the scan spot is 45 km). The location accuracy of the scatterometer data is expected to be + 5 km.

The scatterometer will provide wind speed data over the range

of 2 to 25 m/s with an expected accuracy of ± 2m/s. The wind direction information from the scatterometer will cover the range from 0 to 360 with an expected accuracy of ± 20 .

5.1.2.1.5.1.2 TOPEX/POSEIDON

Besides the data from the ERS-1 satellite, sea-surface topography data and sea-surface wind speed data will also be available from the Ocean Topography Experiment (TOPEX/POSEIDON) which will take place in essentially the same time frame as the ERS-1 experiment. TOPEX is a joint project of the National Aeronautics and Space Administration (NASA) of the United States and the Centre National d'Etudes Spatiales (CNES) of France. The experiment provides for a dedicated earth orbiting satellite that will make radar measurements of the sea-surface. The primary goal of TOPEX is to determine the general circulation of the global ocean and to characterize the time dependent and the time average currents in the ocean. Secondary objectives are to determine the significant tidal component in the sea-surface height field and to determine sea-surface wave characteristics and wind speeds.

The TOPEX/POSEIDON spacecraft is presently planned to be placed in a 10 day repeat orbit in the spring of 1991. The system will be flown at an orbital altitude of approximately 1,334 km (optimal for precision orbit determination) with an inclination angle of 63.1 (optimal for ocean tide determination). The scientific instrument system has been designed for optimal performance by minimizing drag and through careful attention to orbital selection.

The TOPEX/POSEIDON experiment will provide more precise data than the ERS-1. These data can be used in tandem with the ERS-1 altimetry data to provide a finer scale analysis of the sea-surface topography for circulation studies. Furthermore, wind speed (no wind direction) data are also provided by the TOPEX altimetry system but only along the suborbital track. These data can be used to supplement the ERS-1 scatterometer data to develop better spatial wind analyses.

5.1.2.1.5.2 Meteorological Data

The basic meteorological data that will be needed for this research project from in situ meteorological stations are the wind speed and direction information. In the area of interest (approximately 8°N to 32°N latitude and 55°W to 98°W longitude), meteorological data, particularly wind data, are available for the purposes of this research project from coastal weather stations, island stations, and meteorological buoys. For most first order weather stations meteorological data are reported on a six-hour basis as requested by the World Meteorological Organization (WMO). Regardless, tabulated data from most of the first order weather stations suggest that they report on a 3-hour basis. Besides data from first order weather stations, data are also available from other types of meteorological stations. These include air bases, climate stations, and lower order synoptic stations. Not all of these stations, however, provide wind observations.

The in situ wind observation from the meteorological stations will be integrated with the wind observations from the satellite scatterometer to provide wind field analysis over the field in of interest. Great care will be exercised to screen the in situ observations to remove wind data that are associated with long fetches over land and are seriously influenced by continental or island surface frictional forces. Generally, this means that only upwind island and coastal stations and meteorological

buoy data will be utilized. However, screening of the wind data will be performed on a case basis to provide the best possible wind field analyses. The buoy data will not only be integrated to provide the analysis of the wind field, but it will also be used for purposes of calibrating the scatterometer data; i.e., to provide a number of in situ observations which will be used as reference or control points for the establishment of the wind field for the region of interest. Generally, all first order stations report their meteorological observations in real time. On the other hand, meteorological stations other than first weather stations do not report in real time. For the purposes of this research project, all data are obtained after the fact from facilities of the National Climatic Center (NCC).

5.1.2.1.5.3 Ancillary Data

5.1.2.1.5.3.1 Ship Data

During the prelaunch phase and for three years of the ERS-1 and TOPEX/POSEIDON Mission, approximately six months per year of ship time in the CSAR is planned. The Universidad Nacional Autónoma de México - (UNAM) together with the Comisión Oceanográfica Nacional (CON) of Cuba will concentrate on CTD and Pegasus observations in the Yucatan Strait and the Windward Passage; CON will also conduct regional CTD surveys; the Centro de Investigaciones Oceanográficas e Hidrográficas - (CIOH) ship from Colombia will concentrate on CTD observations in the southwestern Caribbean, an area where intense eddy shedding in the Lesser Antilles is suspected to occur; a NOAA vessel from the United States will concentrate on Ametek, CTD, and Pegasus measurements in the Straits of Florida at 27ºN and along the eastern boundary of the Caribbean and the Bahamas. Measurements from these vessels will be used to determine the currents and the sea-level differences across important passages, and to provide data for comparisons with the altimeter-determined dynamic topography.

Farther Southeast, the ORSTOM NOE (Etude de la région Nord-Ouest Equatoriale) programme will provide information on the western boundary currents located in front of French Guyana.

5.1.2.1.5.3.2 Lagrangian Buoys

At about the same time as ERS-1 and TOPEX/POSEIDON, the World Ocean Circulation Experiment (WOCE) will begin. Satellite tracked, free drifting buoys will be released periodically in the North Atlantic as part of WOCE. The NOAA/ARGOS system will be used to track the buoys. For WOCE, tracking information will be acquired every 3 to 4 days in order to reduce the acquisition costs. In a 3 to 4 day period, these buoys could be displayed anywhere from 100 to 600 km, depending on the current speed and on the nature of the circulation. With a 3 or 4 day position acquisition, these buoy data are best used to describe ocean circulation on basin-wide or global scales.

Because of the nature of the near surface flow field in the North Atlantic, it is expected that many of the satellite tracked free drifting buoys that are released by the WOCE programme will be entrained in the CSAR. These data can be used to study the nature of near surface circulation in the region.

This research project will make use of all available free drifting buoy data in the CSAR from the WOCE programme. We have been assured by the WOCE programme that the buoy data will be made available in a timely manner.

5.1.2.1.5.3.3 ACCP Data

The NOAA sponsored Atlantic Climate Change Programme (ACCP) continually monitors the volume transport in the Florida Current between Jupiter, FL and Settlement Point in the Bahamas by submarine cable and by sea-level difference. These data provide daily mean values with accuracies of 1 - 2 x 10 m/s as compared to direct measurements from acoustically tracked dropsondes. Although inflow into the CSAR is unknown in detail, the ACCP data provide a boundary condition on the numerical model as to a constraint on the outflow. One objective of this research is to understand the variability in the volume transport and to simulate the inflow and outflow throughout the CSAR.

5.1.2.1.5.3.4 GLOSS Network and Data

A major programme of the Intergovernmental Oceanographic Commission is GLOSS, the Global Sea-Level Observing System. In the CSAR, over 30 GLOSS quality tide gauges are or will be operating during the timeframe of ERS-1. The gauges are more or less uniformly spread throughout the CSAR, and they will report monthly mean values as part of the IGOSS (Integrated Global Ocean Services System) Pilot Project for the North and Atlantic (ISCPP/NTA). These data will be produced into maps of sea-level departure from the long-term monthly mean by MEDS (Marine Environmental Data Service) of Canada in much the same way as the TOGA sea-level centre does for the Pacific Ocean. Coupled with the NORDA modelling effort and the ERS-1 altimeter observations, the GLOSS data provide additional boundary conditions and calibration information (respectively). In addition, the sea-level data contribute to the global climate studies of the WCRP, WOCE, and IOC-UNEP, and the data acquisition and analysis provides a unifying theme for Training, Education and Mutual Assistance (TEMA) in the region.

Sea-level as measured as a tide gauge is the sum of six terms: gravimetric and radiational tides; water density (temperature and salinity) changes; wind stress; barometric pressure of the atmosphere; volume of water in the ocean; and vertical motion of the gauge itself due to tectonics or subsidence of the land. Recent advances in geodesy and astronomy will provide for the first time the ability to measure the vertical motion of the land. Thus for a tide gauge within about 1000 km of a properly equipped geodetic/astronomic observatory, the true sea-level change due to oceanic and climatic change can be measured. Two such observatories are expected to be operating in the CSAR during this project (and beyond); wholly new insight into oceanography and geophysics will result. If in addition a nearby serial oceanographic station is routinely occupied (such as is proposed for the Cariaco Basin), all six variables can be incorporated into a model for climate change observation that have global significance.

5.1.2.1.5.3.5 NOE Data

ORSTOM sponsors the NOE programme whose leading scientific objective is to study the seasonal variability of the mass and heat transport offshore of French Guyana. The seasonal variability is large there because of the retroflexion of the Guyana current which takes place in June-July following the northward displacement of the ITCZ. This surface circulation seems to have a direct impact on the alongshore displacement of the shoreface attached mud banks. Deep direct current measurements will bring valuable information on the thermohaline circulation at these levels.

5.1.2.2 Legislative Authority

The IOC Sub-Commission for the Caribbean and Adjacent Regions, at its Second Session (Havana, Cuba, 8-13 December 1986) supported the conclusions of the IOCARIBE Workshop on Physical Oceanography and Climate.

The IOC, at the Fourteenth Session of its Assembly, Paris, 17 March - 1 April 1987, accepted the Summary Report and the Recommendations of the Second Session of the Sub-commission for IOCARIBE.

The project follows the recommendations for future actions in the CSAR made by the Joint Meeting of the Task Team on Implications of Climatic Changes in the Mediterranean and the Co-ordinators of Task Teams for the Wider Caribbean Region, South-East Pacific, South Pacific, East Asian Seas and South Asian Seas Regions, Split, Yugoslavia 3 - 8 October 1988.

**5.1.3. Objectives and Achievement Indicators**

To conduct a regional effort to understand the impact of global climate change in the CSAR through quantification and analysis of key parameters subject to control by environmental change. Specifically, the objectives would be:

5.1.3.1 Objectives

(i) Long-term objectives

(a) To increase the knowledge of basin scale ocean circulation in the IOCARIBE Region, knowledge that is central to OSNLR, CEP POL, OSLR, ICCWCR and C & GC.

(b) To reduce scientific uncertainties about the magnitude, direction and possible impacts of climatic and other environmental changes.

(c) To participate in global programmes seeking to understand climatic changes as an IOC contribution to the WCRP (JGOFS, TOGA, WOCE and OOSDP) with the specific objective of improved long- range forecasts for the IOCARIBE Region.

(d) To strengthen existing institutions and improve communication/information exchange between participating institutions.

(e) To increase national capabilities of regional institutions and experts to assess climatic changes and to provide an improved basis for management and prevention of their impacts.

(f) To provide a concrete basis for the evaluation of physical mechanisms in the marine environment within the region, and for the benefit of other programmes such as those regarding dispersion of pollutants and larval transport.

(g) To provide a framework and boundary condition values for the incorporation into numerical models of specific local coastal processes of erosion and sedimentation.

(h) To contribute to UNEP's GEMS and GRID Programmes.

(ii) Short-term objectives

(a) Establishment of a Regional Monitoring Programme for quantifying long-term sea-level, water column and carbon-cycle changes. Specifically:

- measurements of coastal and oceanic sea-level
- wind stress
- temperature and salinity
- spectral radiation levels
- water transparency, (underwater spectral information)
- selected nutrients
- carbon flux (phytoplankton concentration, primary productivity, and sinking carbon flux).

(b) Gather information on the causes of climatic and other environmental changes so as to help to predict future changes and their impacts, to develop and validate numerical models.

(c) Improve professional expertise for regional scientists by active participation in data analysis and interpretation, and publication of results in refereed journals.

(d) Contribute to the case studies of the Caribbean Environmental Programme of UNEP on coastal erosion, river discharge, and impacts on mangroves and on coral reefs.

(e) Develop an easily-accessible portable database, to be updated at a central locale (possibly through telemail). This database should be established on a personal computer and designed to be easily portable to various computers.

(f) Strengthen Training, Education and Mutual Assistance Activities related to climatic change observations, analysis and methodology (including remote sensing and numerical modelling).

5.1.3.2 Achievements indicators for long-term and short-term objectives

(i) For long-term objectives

(a) Data generated and mathematical models developed to predict magnitude of present and future effects of climatic and other environmental changes.

(b) Exchange and flow of information between institutions participating in the Regional Monitoring Programme and between the scientific community and governmental authorities.

(c) Improvement of national, institutional and individual capabilities to assess impacts of climatic and other environmental changes.

(ii) For short-term objectives

(a) Number of scientific institutions reporting data and participating in the Regional Monitoring Programme.

(b) Number of experts trained in measurement of parameters related to climatic and other environmental changes.

### 5.1.4. Outputs, Follow-up Action, Inputs and Assumptions

5.1.4.1 Outputs

(i) An operational Regional Monitoring Programme, providing standardized scientific data on relevant parameters to assess and predict the effects of climatic and other environmental changes in the CSAR.

(ii) Monthly maps of sea-level change from participation in the ISLPP/NTA IGOSS project.

(iii) Altimeter and scatterometer data obtained from satellite remote sensing.

(iv) Oceanographic data for parameters relevant to climatic and other environmental changes obtained from monitoring in coastal areas and through oceanographic cruises.

(v) Experts trained in analysis of remote sensing data and oceanographic measurements for interpretation and prediction of processes relevant to climatic changes.

(vi) Acquisition and supply of equipment for oceanographic and sea-level/weather, measurements and data processing for countries with limited resources.

(vii) Maps on oceanic circulation in the IOCARIBE Region.

5.1.4.2 Use of outputs

(i) Data from the Regional Monitoring Programme and from oceanographic cruises will be used to calibrate and to supplement remote sensing data, as well as other appropriate technology.

(ii) Oceanographic and remote sensing data will be used in modelling oceanic circulation and climatic change in the CSAR in order to obtain a better understanding and prediction of possible impacts.

(iii) Collected data will contribute to the World Climate Research Programme (WCRP), the TOGA, JGOFS, WOCE and OOSDP projects in particular, as well as to UNEP's GEMS and GRID programmes.

(iv) Remote sensing, oceanographic data,and other information gathered will be used in national planning, in particular management of coastal areas, to asses and predict the impact of climatic and other environmental changes.

5.1.4.3 Follow-up actions

The IOCARIBE Secretariat will be responsible for the day-to- day follow-up actions needed and the contacts with institutions involved in the Regional Monitoring Programme. After the establishment of the Regional Monitoring Programme, the institutions involved will continue the monitoring activities under technical supervision and backup from IOC/IOCARIBE.

The IOCARIBE Regional Group of Experts on Physical Oceanography and Climate will provide concrete recommendations to the Member States of IOCARIBE on the required actions to be taken in order to control and prevent

climatic changes relevant to oceanographic processes.

5.1.4.4 Activities

The project will be implemented by IOC through the IOC Secretariat for IOCARIBE in close co-operation with the Regional Co-ordinating Unit for the Caribbean Environment Programme of UNEP.

The IOCARIBE Secretariat will take advice from the IOCARIBE Regional Group of Experts on Physical Oceanography and Climate, the IOCARIBE Regional Group of Experts on Marine Pollution Research and Monitoring and the UNEP/IOC Task Team on Implications of Climatic Changes in the Wider Caribbean Region.

The IOCARIBE Secretariat will, based on experiences from previous activities, coordinate the network of scientific institutions in the region to carry out the monitoring activities. The multidisciplinary character of the impact studies of climatic and other environmental changes will require intensive interactions with different IOC programmes such as GIPME, OSLR and OSNLR as well as with the new International Programme for the Dynamics and Oceanography of Coastal and Shelf Seas and Exchanges.

The following specific activities will be carried out:

(i) Study of Historical Climatology: 1500 - 1900

The aim is to search for historical data in the colonial records of cities around the periphery of the CSAR basin, in order to document previous climatological events of importance. The selected cities are Cartagena (Colombia) Veracruz (Mexico) and Havana (Cuba). People working on this task should coordinate efforts and examine the "Archivo de Indias" in Sevilla (Spain).

(ii) Analysis of Archived Instrumental Data: 1900 - Present

Much of physical oceanographic data from the CSAR has been collected mainly through the U.S. Navy, U.S./NOAA and other national scientific institutions from the region. However, these data are scattered in different countries. It is important to analyze these data, and relate it to data generated through this project to provide the relevant background for the prediction and interpretation of future climatic changes in the region.

(iii) Provision of Observing and Analytic Equipment

The provision of observing and analytical equipment to participating institutions will be required for the proper implementation of the project. Major needs are sea-level recording equipment, CTD's, fluorometers, Niskin sampling bottles, chemical instrumentation and reagents and portable computer equipment. It is essential that a part of the budget be dedicated for spare parts and supplies and training.

(iv) Training, Education, and Mutual Assistance

Within the project, an extensive TEMA component will include individual training; Group training will be provided in particular in the field of sea-level measurement, weather observation, analysis of satellite data and numerical modelling. Emphasis will be placed on procedures of data base design and manipulation, focussing on established large global data bases (World data bases A and B, including NOAA's NODC), and smaller PC -

based and distributed data bases relevant to IOCARIBE.

(v) Completion of Coastal-Oceanographic/Weather Network

The actual coastal oceanographic/weather network has to be extended to encompass the shoreline of the IOCARIBE region; this will allow monitoring the thermal and wind fields and resolution of time and space scales. Based on daily measurements, they will provide useful information on:

(a) coastal trapped waves in the frequency band (1/30 - 1 cycle per year) and to distinguish the waves which are locally free;

(b) seasonal variability associated with coastal upwelling in relationship with the latitudinal displacement of the center of the ITCZ; and

(c) large scale, (decadal) climatic change studies.

(vi) Establishment of Cariaco Basin Oceanographic Time Series

Given the importance of primary productivity in ocean/atmosphere CO2 exchange, the establishment of a long-term serial station in the region to monitor pertinent physical, chemical and biological variables is proposed. The Cariaco basin has been chosen on the basis of both the high biological productivity of surface waters and anoxic conditions below sill depths, where carbon is trapped for an unknown period of time. The high surface productivity occurs in response to the local upwelling regime. The Cariaco Basin thus is a sediment trap where carbon is essentially removed from the ocean/atmosphere system on the scale of hundreds to thousands of years. Periodic cruises on a fortnightly to monthly basis, will be carried out to measure temperature, salinity, nitrates, phosphates, chlorophyll and primary productivity at a serial station in the center of this area. The feasibility of short-term sediment trap deployment (hours) directly from the ship to assess the rates of organic carbon flux at depths of ca. 1000 m will be explored. The Government of Venezuela will be asked to designate the appropriate institutions to undertake this component. It is suggested on the basis of logistic feasibility that this institution be either the Fundación La Salle or the Instituto Oceanográfico de Venezuela. The great importance of this station requires long-term (decades) commitment by the selected institution.

(vii) Extend Oceanographic Observations of passages and Straits

We need to collect hydrographic data in the major passes of the region in order to calibrate sea-level differences observed with the tide gauge regional network and to identify the water masses therein. The oceanographic cruises are also necessary to assess mass flows in the region. This will be done with the contribution of various neighbouring nations, including Cuba, France, Mexico, the United States, Colombia and Venezuela.

The following passes are considered as most important:

- Straits of Florida
- Yucatan Channel
- Windward passage
- Anegada, Jungfern Passage
- The various channels of the northeastern and southeastern Antilles.

(viii) Extend Numerical Modelling Analysis and Data Comparison

Numerical circulation models are being developed that provide eddy-resolving-scale calculations of the 3-dimensional flow. These models need to be capable of data-assimilation, and need to be compared with existing and newly-acquired observational data. Ultimately these diagnostic/prognostic numerical models will be developed into operational forecasting models and made available to organizations for routine use similar to weather forecasting models already operating. To obtain maximum benefit from these state of-the-art numerical models, they will be coupled with biological and chemical numerical models. The development of boundary conditions and data assimilation needs active and continuing inputs from ALL components and nations of the IOCARIBE.

(ix) Establish Satellite Data Archive

To provide a synoptic framework within which an objective analysis of in situ oceanographic observations may be made, satellite data will be archived. The satellite data will be essential to understand time series data collected along the CSAR margins, hydrographic data collected in the island passes and the Cariaco Basin interdisciplinary time series. A possible location for the imagery data archive is the University of South Florida, where extensive hardware and software is available for this purpose, and at the Research Triangle Institute for the altimeter and scatterometer data. The following data sets are essential for the successful understanding of the ISLPP/NTA time series collected throughout the region, and the Cariaco Basin oceanographic time series:

- Coastal Zone Color Scanner (CZCS)
- SeaWifs Ocean Color Scanner (to be launched in 1992)
- ERS-1 altimeter and scatterometer
- TOPEX/Poseidon
- Regional Advanced Very High Resolution Radiometer (AVHRR-Sea-surface temperature)

The data and software will be archived in a format compatible with efficient distribution in a variety of mass- storage media, in particular standard media compatible with personal computers.

(x) Absolute Sea-Level Measurement

The standard way of measuring sea-level does not separate eustatic changes from vertical motions of the land. New methods based on space techniques allow us to measure in absolute terms the position of a point on the Earth's surface to centimeter accuracy. Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), and Global Positioning System (GPS) allow tide gauge location with centimeter accuracy within 1000 km of a VLBI/GPS/SLR reference station. These techniques, along with precise gravity observations can be combined to monitor tide- gauge locations, from which it is potentially possible to separate out eustatic changes from tectonic changes.

(xi) North-South Transect

An oceanographic transect from the coast of Venezuela near the Cariaco Basin to Isla de Aves (approximately along 64°W longitude) will be conducted by the Venezuelan Navy on a monthly basis. To complete the transect from Isla de Aves to the northern Caribbean, the University of Puerto Rico will conduct similar oceanographic surveys bimonthly. These cruises will acquire CTD, nutrient, oxygen, and other data from the surface

to the bottom at regular distances along each transect, and will inter-calibrate several times a year at Isla de Aves. The data will form the basis of a systematic investigation of flow through the eastern Caribbean, with emphasis on a) inflow patterns of surface water, particularly cross-equatorial flow along the coast of French Guiana, and b) deep water renewal from the open Atlantic, with special attention to overflow into the Cariaco Basin. Absolute velocities along each section will be obtained with acoustically tracked dropsondes, and surface waters will be continuously profiled to document riverain discharge into the basin.

5.1.4.5 Organization of the Programme

(i) Participants

The programme will be implemented by a network of scientific institutions in the Region. Among them, for example: the general scientific co-ordination of the programme could be done by AOML/NOAA, Miami and RTI, Raleigh NC. The UNAM (Mexico) and CON (Cuba) will be responsible for obtaining data from parts of the Straits of Florida, Yucatan Strait, the Windward Passage and other adjacent oceanic regions. Shiptime will be provided on research cruises implemented by NOAA, CNO, UNAM, CON, ORSTOM, and CIOH; data from sea-level stations and weather stations will be provided by a great number of national institutions in the region. ORSTOM will provide oceanographic information of the southern boundary. The University of South Florida will be responsible for receiving satellite data and the University of Puerto Rico will establish a long-term serial station to monitor pertinent physical, chemical, and biological parameters.

(ii) Co-ordination

The general supervision for the development and implementation of the programme will be provided by IOC through its Sub-Commission for the Caribbean and Adjacent Regions (IOCARIBE). The regional expertise in the IOCARIBE Group of Experts on Physical Oceanography and Climate will be used to guide the scientific implementation of the programme. The members of the group will be selected in their personal expert capacity.

(iii) Training

Emphasis will be placed on procedures of data base design and manipulation, focusing on established large global data bases (World data bases A and B, including NOAA's NODC), and smaller PC - based and distributed data bases relevant to IOCARIBE.

Intensive individual and collective training will be provided in analysis of remote sensing data and calibration of surface data. Grants will also be provided to allow regional experts to participate in relevant scientific symposia and meetings.

Training to participating scientists will be provided by regionally recognized centres of excellence; including but not restricted to: University of South Florida for remote sensing, NOAA-AOML and RSMAS at Miami, for physical oceanographic and tide- gauge operation and maintenance, and the University of Puerto Rico, Department of Marine Sciences for chemical and biological measurements.

(iv) Equipment

The intensive flow of data from the remote sensing and surface monitoring will require extensive computer facilities and efficient

communication links.

The field monitoring activities, on research vessels and on land, will require field and monitoring equipment.

Equipment for oceanographic measurements and data processing will be provided to allow an increase of the capabilities of all countries in the region.

Communications: telemail for key participating institutions will be provided.

### 5.1.5. Workplan and Budgetary Considerations

The project will run over five years. In order to maintain the IOCARIBE proposal as part of the ERS-1 investigators plan it is vital to have a statement of financial support by the IOC, UNEP and other funding agencies by the end of 1989.

The proposed workplan and budget for the project is presented below. It should be noted that an estimated $8,580,000 in ship time is being committed by IOCARIBE Member States that is not included in the budget. In addition, the salaries of the many participating scientists and technicians, is another contribution in kind to this work.

**WORKPLAN**

| ACTIVITY | RESPONSIBLE | TIMETABLE |
|---|---|---|
| Study of Historical Climatology: 1500 - 1900 | CON,CIOH, UNAM | 1990-1992 |
| Analysis of Archived Instrumental Data: 1900 - Present | CIOH, NOAA | 1990-1992 |
| Provision of Observing and Analytic Equipment | IOCARIBE | 1990-1995 |
| Training, Education, and Mutual Assistance | IOCARIBE | 1990-1995 |
| Completion of Coastal - Oceanographic/Weather Network | NOAA, CNO, CON, ORSTOM | 1991 |
| Establish Cariaco Basin Oceanographic Time-Series | CNO, UPR | 1990 |
| Extend Oceanographic Observations of Passages and Straits | UNAM, CON, NOAA, CNO, ORSTOM | 1990-1995 |
| Extend Numerical Modelling Analysis and Data Comparison | NORDA, NOAA, ORSTOM | 1991-1995 |
| Establish Satellite Data Archive | IOCARIBE (USF,RTI) | 1990-1995 |
| Regional Oceanographic Surveys | CIOH, CON, ORSTOM | 1990-1995 |
| Absolute Sea-Level Measurement | USNO/RSMAS/NOAA, CNO | 1991-1995 |
| Workshops and Expert Consultations | IOCARIBE | 1990,1991 1992,1993 1994 |

Acronyms:

| | |
|---|---|
| CIOH | Centro de Investigaciones Oceanográficas e Hidrográficas |
| CNO | Comisión Nacional de Oceanografía (VEN.) |
| CON | Comisión Oceanográfica Nacional (Cuba) |
| NOAA | National Oceanic and Atmospheric Administration (USA) |
| NORDA | Naval Ocean Research and Development Activity (USA) |
| ORSTOM | Office de la Recherche Scientifique et Technique Outre-Mer (France) |
| RSMAS | Rosenstiel School of Marine and Atmospheric Sciences (Miami) |
| RTI | Research Triangle Institute (USA) |
| UNAM | Universidad Nacional Autónoma de México |
| UPR | University of Puerto Rico |
| USF | University of South Florida (USA) |
| USNO | U.S. Naval Observatory (Miami) |

**BUDGET CONSIDERATIONS**

(US$ in Thousands)

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | TOTAL |
|---|---|---|---|---|---|---|
| Co-ordination | | | | | | |
| - Communication | 10 | 10 | 10 | 10 | 10 | 50 |
| - Scientific Workshops | 15 | 15 | 10 | 10 | 25 | 75 |
| - Travel (operational) | 10 | 5 | 5 | 5 | 10 | 35 |
| Subcontracts | 50 | 50 | 50 | 50 | 50 | 250 |
| Consultants | 25 | 15 | 5 | 0 | 5 | 50 |
| Tema | 25 | 50 | 25 | 25 | 25 | 150 |
| Equipment | 560 | 30 | 30 | 30 | 30 | 680 |
| Reports | 3 | 3 | 6 | 6 | 9 | 27 |
| Data Costs | 10 | 10 | 15 | 15 | 15 | 65 |
| T O T A L ..... | | | | | US$ | 1,382 |

5.2 IMPACTS OF SEA-LEVEL CHANGES ON THE COASTAL ZONE - EFFECTS ON EROSION AND SEDIMENTATION

The Working Group to develop the Project Proposal on Impacts of Sea-Level Changes on the Coastal Zone - Effects on Erosion and Sedimentation was composed by Dr. Georges Vernette (IGBA, France); Dr. Kim Robertson (IGAC, Colombia); Mr. Kenneth Atherley (CCPU, Barbados); Dr. José L. Juanes (CNO, Cuba); Dr. Pedro Roa (UCV, Venezuela); Dr. Maximiliano Bezada (Instituto Pedagógico/Universidad Simón Bolivar, Venezuela); Mr. Bengt Axelsson (IOCARIBE).

The work of the Group is presented below in the form of a Project Proposal.

**5.2.1 Background**

The proposed regional project on the impact of sea-level change on erosion/sedimentation gives priority to the study of beach dynamics and continual monitoring, the production of geomorphological and sedimentary process maps of a comprehensive regional network of monitoring stations. It will therefore fulfil recommendations made at the Second Session of IOCARIBE Sub-Commission (SC-IOCARIBE-II/3) in Havana, Cuba, December 1986.

During the course on Coastal Oceanography held in Cartagena, Colombia in 1988, the recommendations of SC-IOCARIBE-II/3 were endorsed, and the group emphasized the need for TEMA activities oriented towards the study and monitoring of coastal processes. The need for developing standard data collection and analysis method was considered to be critical for developing the understanding of the region's coastal erosion/sedimentation problems.

The need to initiate co-operative and multidisciplinary research in the Caribbean Region and Adjacent Areas, was one of the recommendations made by the Guiding Group of Experts on the OSNLR Programme during the Third Session of the IOC-UN/OALOS meeting in Bordeaux, France in 1989.

Recommendations from the following meetings:

- Havana in 1986 - Mini-Symposium
- Cartagena in 1988 - Course on Coastal Oceanography
- Bordeaux in 1989 - OSNLR Meeting

### 5.2.2 Rationale

The coastal fringe and continental shelves are areas submitted to a marked commercial exploitation, which has significantly increased during the past decades. Besides traditional activities such as fishing, other activities which respond to economic needs have developed, such as industries, aquaculture and tourism, which have led to an ever-increasing exploitation of available resources. In the Caribbean region, most of the population live on the coast and depend highly on marine products for their sustainment.

Beaches represent privileged areas to tourism development and play an important economic role in the Caribbean. However, these are fragile regions and there are many examples of human intervention which have caused irreversible erosion and degradation problems in these areas.

Solid discharges from the continent into the sea are continually increasing; some are related to natural origins, such as rivers, while others are directly attributable to human activities (urban and industrial discharges), and directly or indirectly increase sedimentary processes. The distribution of these discharges into the sea should be exhaustively studied, especially in coral reef and coastal mangrove areas, which represent a natural barrier against coastal erosion.

Coastal ecosystems (mangrove lagoons, deltas, etc.) represent highly productive regions due to the link continent/ocean, and are very fragile. Human intervention, both directly, as well as on the continent itself (as is the case of dams, for example), can seriously affect the coastal environment in these regions.

In view of this situation, positive sea-level can produce significant modifications in the coastal systems, undermining available resources and their rational use. Therefore, all possible impacts of sea-level changes on coastal areas should be studied and assessed.

### 5.2.3 Objectives

(i) Long-Term

Regionally, the project will:

(a) Enhance the understanding of coastal processes and therefore

guarantee improved management of the coastal zone of the Caribbean.

(b) Through an upgraded and ultimately self system comprehensive monitoring network,increase knowledge of spatial and temporal variation in coastal processes and morphological changes throughout the project area.

Nationally, the project will:

Provide relevant knowledge which will form the basis of developing management plans with appropriate financial, legal and institutional mechanisms so that countries, in the future, will be better prepared to cope with sea - level change.

(ii) Short-Term

(a) Prepare inventories of coastal zone resources within the context of bathymetric, topographic and land use patterns.

(b) Establishment of a regional monitoring programme for measuring and quantifying changes in wave regime and coastal landform.

(c) Create and expand regional data base and information exchange facilities, and develop links with World Data Centres A and B.

(d) Conduct TEMA activities in conjunction with regional educational and specialist institutions related to coastal dynamic processes, regarding climatic and other environmental changes.

(e) Conduct joint technical Workshops between resident and non-resident regional scientists so as to facilitate transfer of knowledge and development of specific techniques.

### 5.2.4 General Methodology

The objectives will be reached based on the establishment of a network of monitoring stations distributed throughout the Caribbean and adjacent regions, as well as through data collected via remote sensing and cruise ships.

The Seminar considered that the Project Proposal which arose during the Symposium regarding the impact of climate changes on erosion and sedimentation processes in coastal areas should be re-written before submitting it for approval.

Taking into account the importance of this project, it was agreed that draft should be included in this Report, so that its final wording could be discussed during the IOCARIBE-III Session.

In this regard, it was also proposed to appoint a small group of experts which would meet in Havana, June 1990.

**PROPOSED WORK PLAN**

| ACTIVITY | RESPONSIBLE | YEAR |
|---|---|---|
| Logistic resources inventory | GERC Co-ordinated by IOC-IOCARIBE, UNEP | 1990 |
| Co-ordination meetings | IOC-IOCARIBE | 1990 annually |
| Equipment expansion of station network | Participating countries | 1991 |
| Equipment calibration and methodology | GERC | 1991 |
| Monitoring | GERC | 1991 |
| Measurement calibration in-situ through remote sensors | GERC-NOAA-OMM | 1992 |
| Training Workshops related to the programme | IOC-IOCARIBE | 1991 every 2 yrs. |
| Periodic evaluation of project development | GERC | 1992 every 2 yrs. |
| Coastal management manual elaboration | GERC + Consultant | 1992 |
| Preparation of scientific publications | GERC | 1993 |
| Coastal processes mapping in areas sensible to sea-level changes | GERC, IOCARIBE & participating countries | 1993 |
| Implementation of data bank | IOC-IOCARIBE-UNEP | 1993 |

## 6. ADOPTION OF THE SUMMARY REPORT AND PROPOSALS

**The Seminar adopted** the Summary Report, including the Project Proposal(s) described in section 5.

## 7. CLOSURE

The Chairman, Dr. Hernán Pérez-Nieto, speaking on behalf of the host country, expressed his satisfaction for the results attained during the Seminar. He thanked the work performed by the scientists, particularly those participating in the two Working Groups. He also commended the support provided by the IOCARIBE Secretariat and the local organizers.

Dr. George Maul, on behalf of the foreign experts, expressed similar concepts enlightening the working and scientific atmosphere that prevailed during the meeting.

The Seminar was closed at 18.00 hrs, 1 December 1989.

## ANNEX I

## PROGRAMME OF THE SEMINAR

**TUESDAY 28 NOVEMBER**

| | |
|---|---|
| **Morning** | - Opening by Dr. Enrique Colmenares Finol, Ministro del Ambiente y de los Recursos Naturales Renovables, Venezuela |
| | - Introductory Presentation by Dr. Hernán Pérez-Nieto, Chairman Comisión Nacional de Oceanología |
| **Afternoon** | - Designation of Chairman, Vice-Chairman and Rapporteur |
| | - Scientific Presentations: |
| Mr. Julián Castañeda Mr. Mario Capaldo and Dr. Otto Chourio | Physical Oceanography and Climate Variability in the Coastal Margin of Venezuela: State of Affairs and Projects |
| Dr. José L. Juanes and Dr. Guillermo García | Coastal Stability, Erosion and Sedimentation: the case of Cuba |
| Dr. Jorge Corredor | Mechanisms of eutrophication and examples from Puerto Rico |
| Dr. George A. Maul | Physical oceanography and Climate in the Wider Caribbean including impacts of climate changes and Associated Processes in the Coastal and Shelf Areas |

**WEDNESDAY 29 NOVEMBER**

| | |
|---|---|
| **Morning** | - Scientific Presentations: |
| Mr. Kenneth Atherley | Beach Recovery after Breakwater Modification on the West Coast of Barbados |
| Dr. George A. Maul | Regional Components of the Global Sea-Level Observing (GLOSS) Network |
| Dr. Raúl Mederos | Models of Dispersion of Contaminants |
| Dr. Frank Müller-Karger | Rivers in the Sea; Space-Based Observations of Ocean Colour in the Wider Caribbean Region |

| | |
|---|---|
| Dr. Maximiliano Bezada, Dr. Carlos Suarez and Dr. Pedro Roa | Geomorphological Characterization of the Venezuelan Coasts with emphasis in Erosion and Sedimentation Areas |
| **Afternoon** | - Scientific Presentations: |
| Dr. Kim G. Robertson | Delta Geomorphology along the Colombian Caribbean |
| Dr. Georges Vernette | Geomorphological and Sedimentary Characteristics in the Shelf and Coastal Areas in the Wider Caribbean Region |
| Prof. Gilberto Cedeño and Dr. Darío Bermúdez | Marine-Coastal Contamination Perspectives in Venezuela |
| Dr. Jorge Corredor | Distribution of Petroleum Pollution - the CARIPOL Programme |
| Dr. Christian Colin | Western Boundary Currents as observed in Boreal Summer 1989 |
| **THURSDAY 30 NOVEMBER** | |
| **Morning** | - Working Group discussion and organization |
| | - Plenary discussion |
| **Afternoon** | - Separation in two working groups for development of project proposals |
| **FRIDAY 1 DECEMBER** | |
| **Morning** | - Revision of Project Proposals by the working groups |
| **Afternoon** | - Adoption of Summary Report and Proposals |
| | - Closure |

# ANNEX II

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# ANNEX III

## ABSTRACTS OF SCIENTIFIC PRESENTATIONS

### REGULATION AND MANAGEMENT OF THE MARINE AND COASTAL AREAS IN VENEZUELA

Hernán Pérez Nieto
Instituto de Tecnología y Ciencias Marinas
Universidad Simón Bolivar, Caracas, Venezuela

The most efficient land use and optimum utilization of natural resources, both renewable and non-renewable, in marine-coastal areas of regional developing countries share common characteristics. This is why explaining the Venezuelan situation as a case study can contribute to the understanding of this topic on a regional scale.

In Venezuela this process has gone through the following phases:

() Drawing up an inventory of the current situation, determining the physical characteristics of the territory and - whenever possible - quantifying the existing natural resources (Diagnosis of the current situation).

(ii) Hypothetical projection of what could happen within 25 or 30 years in these areas with the given natural resources, supposing that the current trends remain virtually unchanged (Trend scenario).

(iii) Hypothetical projection of what could happen within 25 or 30 years in these areas with the given natural resources, supposing that corrective measures are drawn up and that these are truly and adequately supported by the relevant agencies. (Desirable and possible scenario or objective image).

### COASTAL STABILITY, EROSION AND SEDIMENTATION: THE CASE OF CUBA

José L. Juanes and Guillermo García
Instituto de Oceanología de la Academia de Ciencias de Cuba

For the Caribbean region, where tourism represents a great source of income, the erosion constitutes not only an environmental problem but a significant economic problem.

El Varadero beach which is the main tourism attraction in Cuba actually presents an erosion of 1.2 m/year. For the corresponding identification of erosion sources, and the formulation of adequate and economic solutions an investigations programme is being implemented since 1979 which includes the following main working areas:

- Geomorphology of the coast and continental shelf
- Morphodynamic
- Sedimentology
- Hydrodynamic

The results achieved until now, have permitted to establish an annual beach cycle and measure the extension of erosion processes.

The geologic-geophysics rising of the shelf showed the existence of sand drainage with enough volume to guarantee the artificial feeding of the beach.

Microscopic analysis of more than 1000 m. sand, shows that it is composed 90% of rests from carbonated calcareous organisms. On the other hand, taking into account a 5 year wind observation, a sediments drawling tendency caused by the action of wind waves through an energetic method, was showed and served to establish a general transport squeme of the continental shelf.

According to these results, a beach recovery project through artificial feeding of the sand was outlined.

During 1988, 60.000 M3 of sand were disposed into an area of 1 km of beach.

Control of morphological variations in a specific sector, permitted to calculate that the loss of sand in a year after the spillings, was only of 20%.

## EUTROPHICATION IN THE CARIBBEAN REGION

Jorge Corredor
Universidad de Puerto Rico, Mayagüez, Puerto Rico

With the exception of the known cases of the Havana Bay in Cuba and the Cartagena Bay in Colombia, the understanding of the causes, processes and consequences of eutrophication in the Caribbean region is extremely limited. Our research, undertaken in the Southern coast of Puerto Rico, shows the effects of eutrophication on the water column and is relatively limited as regards its scope, as it is restricted to the areas immediately adjacent to the sources of pollution. However, the impact can be severe with regard to the flourishing of filamentous cyanophytes and toxic dinoflagellates.

The most long-lasting impact is on the coastal marine benthos, where accumulation of organic matter from rotting seaweed produces total anoxia and the exclusion of bentonic communities. Unlike the coastal ecosystems in milder climate regions, in the tropics the reduced availability and the rapid intake of oxygen prevent the use of excess nitrogen made available through joint processes of nitrification and denitrification. This is why our tropical coastal ecosystems are much more vulnerable to the eutrophication processes than their counterparts in seas of milder climates.

## PHYSICAL OCEANOGRAPHY AND CLIMATE IN THE WIDER CARIBBEAN INCLUDING IMPACTS OF CLIMATE CHANGES AND ASSOCIATED PROCESSES IN THE COASTAL AND SHELF AREAS

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A summary of the IOC/UNEP sponsored study of the expected impact of a 20 cm rise in sea-level and a 1.5 C rise in temperature by the year 2025, due to a doubling of greenhouse gases, was presented. The 20 cm/1.5 C scenario was compared to observations, and it was shown that due to plate tectonics the sea-level rise is expected to be very localized; the temperature change is equally difficult to observe due to large interannual variability caused by other global signals such as the ENSO. On a regional basis, if one accepts the 20 cm/1.5 C scenario, the impacts are expected to be moderate except for sea level effects on deltas and beaches, which will suffer exacerbated changes; temperature effects are considered important to increased number and strength of tropical storms. The report emphasizes that these impacts reflect only the 20 cm/1.5 C scenario and are considered as effects that worsen other problems such as population pressure, pollution, warfare, subsidence, coastal erosion, and construction.

## SHORELINE RESPONSE TO DIRECT HUMAN INTERVENTION ON THE WEST COAST OF BARBADOS

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The paper describes the nature of shoreline response to reef disruption and sea defenses construction along a half kilometer stretch of beach at the Barbados Beach Village Hotel (B.B.V..) on the Barbados West Coast.

Aerial photography for 1954 showed a beach width of 17-20 m. at the headland. However, it appears that reef clearing to facilitate boat traffic near a jetty in the early 1970s, led to progressive erosion. The onset of erosion in turn resulted in a chain of actions, some successful, others not so successful: the two short groynes in the 1970s had no impacts; the one long 68m. groyne in 1981 led to updrift accretion and downdrift erosion; the 1983 groyne modification into a breakwater released sediment to the downdrift,, but erosion on the updrift set in and did not stop; efforts to stem the erosion led to the erection of a second breakwater on the north of B.B.V. in 1986. This has not proven to be successful.

The stages of sea defence work represented varying responses to erosion or unequal sand distribution by government as well as by the property owners. It was demonstrated that these sea defenses may not always be necessary, and that shoreline conditions should be fully assessed prior to, during, and after defence construction. The case for retaining fringing reef as intact natural systems is fully stressed. The B.B.V. experience also illustrated the need for trained coastal scientists to have direct inputs to the planning process.

## REGIONAL COMPONENT OF THE GLOBAL SEA-LEVEL OBSERVING (GLOSS) NETWORK

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A global sea-level observing system is being co-ordinated by the IOC, and the IOCARIBE component is being used as a model for other regional programs. The value of multi-decade and longer sea-level records was shown to have significant climate- change information, and sea-level difference across straits and between islands was shown to be an excellent indicator of ocean currents. The IGOSS Sea-Level Pilot Project for the North and Tropical Atlantic (ISLPP/NTA) is the framework for a TOGA-like monitoring system, and is being implemented with IOCARIBE participation. The role of satellite-reporting sea-level/weather stations in monitoring climate change and ocean currents, for calibration of satellite altimeters, to complement juxtaposed serial oceanographic stations, in marine transportation and safety, and as vertical surveying datum for economic development, was discussed. Lastly, the use of new space and astronomical methods to separate true sea-level change from land motion using VLBI, GPS, SLR, and the GLRS, was discussed, with emphasis on the unique position of sea-level/weather stations in the Gulf/Caribbean/Bahamas region to capitalize on these new geodetic technologies.

## RIVERS IN THE SEA; SPACE-BASED OBSERVATIONS OF OCEAN COLOR IN THE WIDER CARIBBEAN REGION

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Multi-year (1979-1982) series of Coastal Zone Color Scanner (CZCS) satellite images covering the western tropical Atlantic were combined to yield monthly representation of the mean and standard deviation surface pigment fields. When these composites were compared with historical hydrographic information, a consistent pattern in the surface circulation was revealed. Pigment patches related to upwelling and river plumes remained coherent and traced the circulation. We found that the "standard" pigment-concentration algorithms (Gordon et al., Journal of Geophysical Research, 93:D9, 10909-10924, 1988) failed near the coast where suspended sediments are high. Offshore, pigment concentrations in the river plumes appeared to be realistic, but problems of interpretation due to high concentrations of dissolved organic matter remain.

The composites suggested that early in the year there is a strong flow along northern South America which carries Amazon water directly toward the Caribbean Sea (Müller-Karger et al., 1988, Nature, 333, 56-59). At this time the discharge of the Orinoco River is low, and its plume

remains within the southern Caribbean (south of 15°N). After June, the North Brazil Current is shunted eastward, carrying with it a large fraction of Amazon water into the North Equatorial Countercurrent (NECC). Amazon water spreads eastward, reaching over more than 2000 km away from the continent and is visible near Africa. The seasonal formation of the NECC seems to cause diminished flow through the eastern Caribbean. This permits the northwestward dispersal of Orinoco water due to the local (eastern Caribbean) Ekman forcing (Müller-Karger et al., in press in Progress in Oceanography, 1990). The Orinoco plume at this time extends 1000 km across the Caribbean, leading to the seasonal variation of sea surface salinity observed near Puerto Rico.

Based on recent and historical information on the concentration of phytoplankton in the western tropical Atlantic, we concluded that at least 50% of the concentration of pigments estimated using Gordon et al.'s CZCS algorithm is due to viable phytoplankton. Due to the important socio-economic impact of upwelling and river discharge in the wider Caribbean region, we need to begin time series of observations of phytoplankton pigment concentration, dissolved organic matter concentration. and water-leaving radiance in several locations in the Caribbean. These measurements are essential for proper interpretation of data to be collected in the mid 1990's with new space-based ocean color scanner.

## GEOMORPHOLOGICAL CHARACTERIZATION OF THE VENEZUELAN COASTS WITH EMPHASIS ON EROSION AND SEDIMENTATION AREAS

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The geomorphological characteristics of Venezuelan coasts are due to geological and marine elements; here, coastal areas with tectonic influence can be found, where the erosive processes are basic, as well as areas where the coastal regularization processes due to sedimentation are predominant.

The geological influence (lithological and tectonic) determines many characteristics in some coastal areas; for example, the cliffs on the coast between Puerto Cabello and Cabo Codera are strongly influenced by the Moron and Macuto flaws. The size, erosiveness, and climate of the drainage basins affect the supply of debris to the coast and the development of elements associated to sedimentation, as is the case of the deltas of the Orinoco, Unare and Mitare Rivers. Carbonatic build-up is significant in certain areas, such as Tucacas-Chichiriviche, Tocuyo de la Costa, and near the San Roman Cape. Another important biological influence is mangrove vegetation, which promotes sedimentation and advance of the shoreline when wave erosion diminishes.

Sea action is mainly through waves and coastal currents, as tides are of slight importance due to their magnitude. Drifts and coastal currents maintain a persistent westward direction, and are responsible for sediment transportation along the coast. The tidal current is of slight importance, and this, along with the abundance of sediments, has contributed to the narrowing of the mouth of coastal lagoons in the Midwestern coast, causing problems due to the accelerated sedimentation process.

The absence of sedimentation areas in regions near important urban centers has lead to the construction of engineering projects for the creation of beaches, as is the case of the central coast (between La Guaira and Los Caracas). When erosion areas affect urban habitats, the government becomes involved, but when this is not so, they are only receive attention from researchers interested in these processes. At present, the eroded areas in the northern coast of Margarita (La Guardia), in the sand bank of the Unare Lagoon (western sector), in the Chichiriviche Cove and Aguide (both in Falcon), are being studied in order to propose adequate solutions.

## DELTA GEOMORPHOLOGY ALONG THE COLOMBIAN CARIBBEAN

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Recent studies along the Colombian Caribbean coastline indicate that delta geomorphology in general responds to Galloway's classic model in which basic elements include: (i) water and sediment input, (ii) wave action, and (iii) tides. Nevertheless, along the Caribbean coastline several delta anomalies have been identified which suggest the presence of at least three other factors: (i) bathymetric, (iii) structural and (iii) relic geomorphic conditions.

Structural control of the coastal platform is suggested by asymmetrical fluvial and delta axis aligned along the western flanks of the Magdalena and Atrato deltas. In the Sinú delta, relic geomorphic conditions due to prograding have determined variable delta morphology during the upper Holocene. As a general conclusion, though Galloway's model provides a basis for delta analysis, bathymetric, structural and relic geomorphic control should also be considered during delta studies.

## GEOMORPHOLOGICAL AND SEDIMENTARY CHARACTERISTICS OF THE SHELF AND COASTAL AREAS IN THE WIDER CARIBBEAN

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Through examples chosen from the Caribbean and adjacent regions, the influence of the three main parameters responsible for the geomorphological and sedimentary characteristics of the coasts and continental shelves is illustrated.

(i) Geological framework: the relative displacement of the Caribbean platform towards the east forms narrow continental shelves, with steep slopes in the eastern flanks (Lesser Antilles Arc) and western flanks (Central America). The shelves of the northern flanks (Greater Antilles) and southern flanks (South American continent) are associated with the great directional flaws which mark the boundaries of the Caribbean with respect to its northern and southern neighbours. On the other hand, the Gulf of Mexico, which is part of the North American shelf, is characterized by a wide continental shelf with moderate slopes.

(ii) Continental sedimentary contribution: these contributions are usually small, except in the coastal areas of the two great continents with borders in the Caribbean (Gulf of Mexico and northern strip of South America). The deltas of the three main rivers (Mississippi, Orinoco and Magdalena), are located at the site of massive sediment movements (slumps, clayish diapairism).

(iii) Climatic and hydrological conditions: these parameters have a distinct performance in the coastal area and are responsible for the development of coral reef formations, as well as for sediment distribution. The microtidal character of tides in the Gulf of Mexico favours the formation of numerous lagoons, separated from the sea by a sandy barrier. The annual cyclical variations o the morphosedimentary coastal characteristics can be irreversibly modified due to cyclones or human intervention.

## MARINE-COASTAL CONTAMINATION PERSPECTIVES IN VENEZUELA

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Approximately 50% of the Venezuelan population resides on the Caribbean Sea Basin, which contributes approximately 1% of total water discharge. This is why rivers which drain directly into the Caribbean Sea can be considered good indicators of the pollution produced by domestic, industrial and agricultural activities.

The massive amount of pollutants transported by these rivers fluctuates and depends on each river's volume, the time of the year and other associated processes. Although the volume of certain rivers is known, the scarce information available regarding industries located on the river banks prevents a detailed understanding of existing environmental problems.

On the other hand, there are no systematic or prolonged studies to support estimates of stational variations, distribution and final destination of pollutants discharged by rivers into the Caribbean Sea each year.

Due to the insufficient data available on the amount of pollutants discharged by rivers and sewages, an assessment of the pollution coming from land sources cannot be carried out. The oil industry is a good example; refineries dump their discharges near the coast, and the chemical composition and form of insertion is unknown. The dispersal area of these pollutants is influenced by their nature and by the hydrodynamics of the water, which could be expanded due to the persistency of these toxic products in the environment and to the mobilization of contaminated marine organisms.

The rivers located in southeast Venezuela, specially the San Juan and Orinoco Rivers, are among the main pollution spreaders towards the Caribbean.

An investigation geared towards the determination of the pollution volume, its origins, distribution and destination in the Caribbean implies a multidisciplinary effort, involving experts in environmental pollution and oceanic processes.

## DISTRIBUTION, DISPERSION AND PERSISTENCE OF PETROLEUM POLLUTION IN THE CARIBBEAN REGION - THE CARIPOL PROGRAMME

Jorge E. Corredor
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The investigations performed during the development of the CARIPOL Programme, show that the distribution of petroleum contaminants in the marine environment of the Caribbean and adjacent regions depends, on one hand, on the production, use and transport of these components and on the other hand, from the flow of surface water in the region. Therefore, preliminary results from the Phase II of the CARIPOL Programme in which contaminants in sediments and organisms are analyzed indicate that accidentally or intentionally, discharged petroleum into the sea is subject to rapid physical, chemical and biological degradation. Once these components reach the coastal area, its persistence increases in an insidious way. Due to economic, ecologic and aesthetic importance of the coastal ecosystems, such a persistence makes up a serious problem which should be subject to detailed studies for its eventual control.

## WESTERN BOUNDARY CURRENTS AS OBSERVED IN BOREAL SUMMER 1989

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The ORSTOM (Office de la Recherche Scientifique et Technique Outre Mer) sponsored NOE (Etude de la region Nord-Ouest Equatoriale) programme has for main objective the study of the seasonal variability of mass and heat transports associated with the Guyana Current (GC). As observed from the shipdrift, SEQUAL/FOCAL satellite drifting buoy tracks and surface current

simulations drawn for the GFDL Global Circulation Model, GC (continuity of the South-Equatorial Current and North Brazil Coastal Current) veers to the East in May-June; this phenomenon called "retroflexion effect" occurs when the NECC (North Equatorial Counter Current) is at its maximum strength following the Northward displacement of the ITCZ (Inter Tropical Convergence Zone). Therefore the Gulf Stream seems to be not feeded all the year long with Western warm Equatorial waters and Amazone river fresh waters. The NOE programme starts in May 1989 and will be finished in mid-1991.

From now, three cruises have been carried out by the ORSTOM R/V ANDRE NIZERY in May (12-22), June (2-12) and July (4-13) with transects from the coast to 300 m.m. offshore; one transect in front of Cayenne has also been made during the STACS cruise No. 34 on-board the NOAA R/V MALCOLM BALDRIDGE. The observations collected support the previous observations; (i) in May, GC is located on the continental shelf with surface speed up to 120cm/s; (ii) in June, GC maximum development is observed both on and offshore; the mean speed is of the same order of magnitude as in May; (iii) in July, on the contrary, the current is weaker and in opposite direction; this is an agreement with the shipdrift observations of the R/V ANDRE NIZERY between Cayenne and Fortaleza (07/17-25/1989) which shows an anticyclonic movement South of Cayenne. The surface distributions of the temperature and salinity present a frontal zone in agreement with the retroflexion area. The surface current seems to have a large impact on the alongshore displacement

of the shorefaced attached mudbanks in front of Cayenne; the satellite pictures show that if the mean Northward displacement of the mudbanks is around 900 m/year from December to March, it is on the contrary very weak (less than 50m/year) from July to October. Deeper, between 200 m and 300 m depth, the circulation pattern is the negative picture of the surface one: the mean speed observed is around 60 cm/s at the shelf break. September (Pegasus profiles) is the period during which the subsurface current is the more developed ( 200cm/s), but now offshore; at the shelf break, the current is strongly (around 180 cm/s) Northward; the current at that level and for that particular period of the year presents an anticyclonic direction; this is an agreement with the Community Model Current Simulation at that level. Below 1000 m. level which corresponds to a minimum current speed for the four Pegasus profiles, the currents are again in opposite direction to above: South-eastward Current at the shelf break with a mean speed up to 50 cm/s from 1000 m depth to the bottom and North-westward beyond the isobath 3000 m; the loop is now in a cyclonic sense and both currents are associated with a maximum of salinity.

These measurements will continue in 1990; five cruises are scheduled with the ORSTOM R/V ANDRE NIZERY (January, February, March, October, November) and two with a NOAA research vessel. The NOE programme is strongly related to the NOAA STACS programme in which the NOAA-AOML of Miami, the University of Miami and the University of Kiel (West Germany) are involved.

## ABSOLUTE SEA-LEVEL MEASUREMENT IN FLORIDA AND THE WIDER CARIBBEAN REGION

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We describe a system to measure true sea-level changes from the U.S. Naval Observatory in south Florida. The standard way of measuring sea-level does not separate eustatic changes from vertical motions of the land. However, the geology of Florida is relatively simple, consisting mainly of shallow water carbonates laid down over a slowly subsiding platform with very few major faults, meaning that tectonic regimes should be similar everywhere. Thus height variation in widely separated regions within the state can be related to each other directly by rather simple geodetic ties. New methods based on space techniques allow us to measure in absolute terms the position of a point on the Earth's surface to centimeter accuracy. Very Long Baseline Interferometry (VLBI) uses signals from a number of quasars to measure position displacements between pairs of VLBI stations to sub-centimeter level. Satellite Laser Ranging (SLR), which has been collocated with the Naval Observatory VLBI station, uses laser pulses reflected from the LAGEOS satellite back to the originating station to determine the station position at the + 1 cm level in geocentric coordinates. We propose to use Global Positioning System (GPS) receivers to locate tide-gauges with respect to the Observatory, initially along the Florida coast, and in due course throughout the Wider Caribbean Region. This can be done with centimeter accuracy within 1000 km of a VLBI/GPS

reference station once GPS is fully operational. In addition, the Earth Observing System will deploy a Geodynamic Laser Ranging System (GLRS), in which a laser system and receiving telescope are mounted on a polar orbiting satellite, allowing measurements to be made by deploying corner reflectors located on Earth. This will increase significantly the number of tide stations that can be accurately located. The University of California at San Diego and the Institute for Applied Geodesy, Frankfurt FRG, in co-operation with the National Geodetic Survey and the Naval Observatory, respectively, have installed two superconducting gravity meters at the USNO station in Miami. The measured gravitational effects can be related to sea-level variations and other meteorological and water loading effects. If these techniques can be combined to monitor tide-gauge locations, it is potentially possible to separate out eustatic changes from tectonic changes.

## ANNEX IV

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACCP | Atlantic Climate Change Programme |
| AIW | Antartic Intermmediate Water |
| AOML (of NOAA) | Atlantic Oceanographic Meteorological Laboratory |
| CEP POL | Regionally Co-ordinated Comprehensive Programme for Marine Pollution Assessment and Control for the Caribbean |
| CGC | Climate and Global Changes |
| CIOH | Centro de Investigaciones Oceanográficas e Hidrográficas |
| CNES | Centre National d'Etudes Spatiales |
| CSAR | Caribbean Sea and Adjacent Regions |
| CTD | Conductivity, Temperature, Depth |
| ESA | European Space Agency |
| GPS | GARP Publications Series |
| GEMSI | Group of Experts on Methods, Standards and Intercalibration |
| GIPME | Global Investigation of Pollution in the Marine Environment |
| GLOSS | Global Sea-Level Observing System |
| GRID | Global Resource Information Data Base |
| IAPSO | International Association for the Physical Sciences of the Ocean |
| ICCWCR | Implications of Climatic Changes in the Wider Caribbean Region |
| ICSU | International Council of Scientific Unions |
| IGOSS | Integrated Global Ocean Services System |
| IOC | Intergovernmental Oceanographic Commission |
| ITCZ | Intertropical Convergence Zone |
| JGOFS | Joint Global Ocean Flux Studies |
| MARPOLMON | Marine Pollution Monitoring |

| | |
|---|---|
| MEDS | Marine Environmental Data Service |
| NASA | National Aeronautics and Space Administration |
| NCC | National Climatic Center |
| NOAA | National Oceanic and Atmospheric Administration |
| NOE (NORSTOM) | Etude de la Région Nord-ouest Equatoriale |
| NORDA | Naval Ocean Research and Development Activity |
| OOSDP | Ocean Observing System Development Programme |
| ORSTOM | Office de la Recherche Scientifique et Technique Outre Mer |
| OSLR | Ocean Science in relation to Living Resources |
| OSNLR | Ocean Science in relation to Non-Living Resources |
| RCU/CEP | Regional Co-ordination Unit of the Caribbean Environmental Programme |
| SAR | Synthetic Aperture Radar |
| SSH | Sea-Surface Height |
| STACS | Sub-Tropical Atlantic Circulation Study |
| SUW | Sub-Tropical Under Water |
| TEMA | Training, Education and Mutual Assistance in the Marine Sciences |
| TOGA | Tropical Oceans and the Global Atmosphere |
| UNAM | Universidad Nacional Autónoma de México |
| UNEP | United Nations Environment Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| VLBI | Very Long Baseline Interferometry |
| WCRP | World Climate Research Programme |
| WMO | World Meteorological Organization |
| WOCE | World Ocean Circulation Experiment |

| No. | Title | Publishing Body | Languages |
|---|---|---|---|
| 33 | Workshop on the IREP Component of the IOC Programme on Ocean Science in Relation to Living Resources (OSLR) Halifax, 26-30 September 1983 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 34 | IOC Workshop on Regional Co-operation in Marine Science in the Central Eastern Atlantic (Western Africa) Tenerife 12-17 December 1983 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English French Spanish |
| 35 | CCOP/SOPAC-IOC-UNU Workshop on Basic Geo-scientific Marine Research Required for Assessment of Minerals and Hydrocarbons in the South Pacific Suva, Fiji, 3-7 October 1983 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 36 | IOC/FAO Workshop on the Improved Uses of Research Vessels Lisbon, 28 May - 2 June 1984 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 36 Suppl. | Papers submitted to the IOC-FAO Workshop on Inproved Uses of Research Vessels Lisbon, 28 May-2 June 1984 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 37 | IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 37 Suppl. | Papers submitted to the IOC/Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs Colombo, 8-13 July 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 38 | IOC/ROPME/UNEP Symposium on Fate and Fluxes of Oil Pollutants in the Kuwait Action Plan Region Basrah, Iraq, 8-12 January 1984 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 39 | CCOP (SOPAC)-IOC-IFREMER-ORSTOM Workshop on the Uses of Submersibles and Remotely Operated Vehicles in the South Pacific Suva, Fiji, 24-29 September 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 40 | IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications Sidney, B.C., Canada, 29-31 July 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 40 Suppl. | IOC Workshop on the Technical Aspects of Tsunami Analyses, Prediction and Communications *Submitted Papers* Sidney, B.C., Canada, 29-31 July 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 41 | First Workshop of Participants in the Joint FAO/IOC/WHO/IAEA/UNEP Project on Monitoring of Pollution in the Marine Environment of the West and Central African Region (WACAF/2) Dakar, Senegal, 28 October - 1 November 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 43 | IOC Workshop on the Results of MEDALPEX and Future Oceanographic Programmes in the Western Mediterranean Venice, Italy, 23-25 October 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 44 | IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English (out of stock) Spanish |
| 44 Suppl. | IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities - *Submitted Papers* Ciudad del Carmen, Campeche, Mexico, 21-25 April 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 45 | IOCARIBE Workshop on Physical Oceanography and Climate Cartagena, Colombia, 19-22 August 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 46 | Reunión de Trabajo para Desarrollo del Programa «Ciencia Oceanica en Relación a los Recursos No vivos en la Región del Atlantico Sudoccidental Porto Alegre, Brazil 7-11 de Abril de 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | Spanish |
| 47 | IOC Symposium on Marine Science in the Western Pacific: The Indo-Pacific Convergence Townsville, 1-6 December 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 48 | IOCARIBE Mini-Symposium for the Regional Development of the IOC-UN (OETB) Programme on "Ocean Science in Relation to Non-Living Resources (OSNLR)" | IOC, Unesco Place de Fontenoy 75700 Paris, France | English Spanish |
| 49 | AGU-IOC-WMO-CPPS Chapman Conference: An International Symposium on "El Niño" Guyaquil, Ecuador, 27-31 October 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 50 | CCAMLR-IOC Scientific Seminar on Antarctic Ocean Variability and its Influence on Marine Living Resources, particularly Krill (organized in collaboration with SCAR and SCOR) Paris, France, 2-6 June 1987 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 51 | CCOP/SOPAC-IOC Workshop on Coastal Processes in the South Pacific Island Nations, Lae, Papua-New Guinea, 1-8 October 1987 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 52 | SCOR-IOC-Unesco Symposium on Vertical Motion in the Equatorial Upper Ocean and its Effects upon Living Resources and the Atmosphere Paris, 6-10 May 1985 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 53 | IOC Workshop on the Biological Effects of Pollutants Oslo, 11-29 August 1986 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 54 | Workshop on Sea-level Measurements in Hostile Conditions Bidston, UK, 28-31 March 1988 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 55 | IBCCA Workshop on Data Sources and Compilation Boulder, Colorado, 18-19 July 1988 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 56 | IOC/FAO Workshop on Recruitment of Penaeid Prawns in the Indo-West Pacific Region (PREP) Cleveland, Australia, 24-30 July 1988 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |
| 57 | IOC Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms Takamatsu, Japan, 16-17 November 1987 | IOC, Unesco Place de Fontenoy 75700 Paris, France | English |