Intergovernmental Oceanographic Commission
Training Course Reports **39**

IOC/GLOSS-GOOS Training Workshop on Sea-Level data Analysis

Geodetic & Research Branch
Survey of India

Dehra Dun, India
21 November-1 December 1995

UNESCO

IOC Training Course Reports

No.	Title	Language versions
1.	IOC Indian Ocean Region Training Course in Petroleum Monitoring Perth, 18 February-1 March 1980	English
2.	IOC Regional Training Course for Marine Science, Technicians Cape Ferguson, Queensland, 1-28 June 1980	English
3.	ROPME-IOC-UNEP Training Workshop on Oceanographic Sampling Analysis, Data handling and Care of Equipment, Doha, Qatar, 3-15 December 1983	English
4.	Stage COI d'initiation à la gestion et au traitement de l'information scientifique et technique pour l'océanologie, Brest, France, 28 novembre - 9 décembre 1983	French
5.	Curso mixto COI-OMM de formación sobre el Sistema Global Integrado de Servicios Oceánicos (SGISO), Buenos Aires, Argentina, 15-26 de octubre de 1984	Spanish
6.	UNESCO-IOC-NBO Training Course on Tidal Observations and Data Processing Tianjin, China, 27 August - 22 September 1984	English
7.	Stage COI sur la connaissance et la gestion de la zone côtière et du proche plateau continental Talence, France, 18 septembre - 4 octobre 1984	French
8.	IOC Regional Training Course on Marine Living Resources in the Western Indian Ocean Mombasa, Kenya, 27 August - 22 September 1984	English
9.	IOC-UNESCO Summer School on Oceanographic Data, Collection and Management Erdemli, Icel, Turkey, 21 September - 3 October 1987	English
10.	IOC-UNESCO Regional Training Workshop on Ocean Engineering and its Interface with Ocean Sciences in the Indian Ocean Region, Madras, India, 17 March - 5 April 1986	English
11.	IOC-UNESCO Training Course on the Use of Microcomputers for Oceanographic Data Management Bangkok, Thailand, 165 January - 3 February 1989	English
12.	IOC Advanced Training Course on Continental Shelf Structures Sediments and Mineral Resources Quezon City, Philippines, 2-13 October 1989	English
13.	IOC/IODE Training Course on GF3 Data Formatting System Obninsk, USSR, 14-24 May 1990	English
14.	IOC Training Course on Microcomputers and Management of Marine Data in Oceanographic Data Centres of Spanish-speaking Countries, Bogotá, Colombia, 21-30 October 1991	English Spanish
15.	IOC Advanced Training Course on Nearshore Sedimentation and the Evolution of Coastal Environments, Kuala Lumpur, Malaysia, 17-29 February 1992	English
16.	First IOC Training Course on the Applications of Satellite Remote Sensing to Marine Studies Caracas, Venezuela, 24-28 September 1990	English
17.	IOC-KMFRI-RECOSCIX (WIO) Regional Training Course on Microcomputer-based Marine Library Information Management, Mombasa, Kenya, 10-21 August 1992	English
18.	ROPME-IOC Regional Training Course on Management of Marine Data and Information on Microcomputers for the ROPME Region, Kuwait, 18-28 October 1992	English
19.	IOC-SOA Training Workshop on Environmental Effects on Benthic Communities Xiamen, China, 19-23 October 1992	English
20.	IOC Training Course for the Global Sea Level Observing System (GLOSS) directed to the African and South American Portuguese and Spanish-Speaking Countries São Paulo, Brazil, 1-19 February 1993	English
21.	IOC-SSTC-SOA Training Course on Marine Information Management and ASFA Tianjin, China, 19-30 October 1992	English
22.	First IOC/IOCARIBE-UNEP Training Course on Monitoring and Control of Shoreline Changes in the Caribbean Region, Port-of-Spain, Trinidad and Tobago, 21-30 July 1993	English Spanish
23.	IOC/WESTPAC Training Course on Numerical Modelling of the Coastal Ocean Circulation Matsuyama, Japan, 27 September - 1 October 1993	English
24.	IOC-JODC Training Course on Oceanographic Data Management Tokyo, Japan, 28 September - 9 October 1992	English
25.	IOC-JODC Training Course on Oceanographic Data Management Tokyo, Japan, 27 September - 8 October 1993	English
26.	IOC Training Course on Ocean Flux Monitoring in the Indian Ocean. Organized with the support of the Government of Germany, Mombasa, Kenya, 15-27 November 1993	English
27.	IOC-UNEP-SPREP Training Course on Coral Reef Monitoring and Assessment Rarotonga, Cook Islands, 23 February - 13 March 1994	English
28.	IOC-JODC Training Course on Oceanographic Data Management Tokyo, Japan, 26 September - 7 October 1994	English
29.	IOC-UNEP-WHO-FAO Training Course on Qualitative and Quantitative Determination of Algal Toxins Jena, Germany, 18-28 October 1994	English
30.	IOC Training Course on Oceanographic Data Management for the Black Sea Countries Obninsk, Russian Federation, 1-12 August 1994	English
31.	COI-CEADO Curso Regional de Capacitación en Gestión de Datos e Información Oceanográficos Buenos Aires, Argentina, 17-28 de octubre de 1994	Spanish
32.	IOC-UNEP-FAO Training Course on Nutrient Analysis and Water Quality Monitoring Zanzibar, Tanzania, 21-26 November 1994	English
33.	IOC-IOMAC Advanced Training Course on Marine Geology and Geophysics off Pakistan. Pakistan, 12-26 November 1994	English
34.	Training Course on Management of Marine Data and Information for the Mediterranean Region Valletta, Malta, 10-21 April 1995	English
35.	IOC-UNEP-WHO-FAO Training Course on Toxin Chemistry and Toxicology related to Harmful Algal Blooms Trieste, Italy, 3-12 September 1995	English
36.	MAST-IOC Advanced Phytoplankton Course on Taxonomy and Systematics Naples, Italy, 24 September - 14 October 1995	English
37.	IOC-JODC Training Course on Oceanographic Data Management Tokyo, Japan, 16-27 October 1995	English
38.	IOC/IODE Training Course on Marine Geological and Geophysical Data Management Gelendzhik, Russian Federation, 13-29 September 1995	English
39.	IOC/GLOSS-GOOS Training Workshop on Sea-Level Data Analysis, Geodetic & Research Branch Survey of India, Dehra Dun, India, 21 November-1 December 1995	English

Intergovernmental Oceanographic Commission

Training Course Reports

39

IOC/GLOSS-GOOS Training Workshop on Sea-Level data Analysis

Geodetic & Research Branch
Survey of India

Dehra Dun, India
21 November-1 December 1995

UNESCO

TABLE OF CONTENTS

SUMMARY REPORT

ANNEXES

1. INTRODUCTION

The **GLOSS-GOOS Training Workshop on Sea-Level Data Analysis** was held at the Geodetic & Research Branch, Survey of India, Dehra Dun, India, 21 November - 1 December 1995, at the initiative of the Intergovernmental Oceanographic Commission (IOC) under the auspices of the **IOC-UNEP-WMO Pilot Activity on Sea-Level** Changes and Associated Coastal **Impacts (see Document** IOC/INF-908) which is being implemented in the Indian Ocean since 1993.

The two primary objectives of this Pilot Activity are: (i) To improve understanding of the processes that control sea-level variability at sites where sea-level is monitored in the Indian Ocean. (ii) To enhance capabilities of countries of the Indian Ocean to monitor and analyze sea-level data. The Pilot Activity envisages setting up of a network of Cell for Monitoring and Analysis of Sea-level (CMAS). The tasks of the scientists associated with each CMAS are to secure high quality sea-level data, to analyze these data to identify important features of variability, and to undertake research to understand the causes behind these features.

In response to the appeal from the IOC to participate in the Pilot Activity, the following countries have established CMAS: Bangladesh, India, Kenya, Madagascar, Malaysia, Maldives, Mauritius and Mozambique. In addition, Tanzania participates in the activities of the Pilot Activity, Seychelles has offered to support it by making sea-level data from its stations available to interested researchers, Australia, through its National Tidal Facility, provides active support to the Pilot Activity and Sri Lanka has expressed interest in setting up a CMAS in the near future.

Scientists associated with implementation of the Pilot Activity met at a planning workshop in Zanzibar, Tanzania, 17-21 January 1994, The workshop concluded that the most important challenge for the Pilot Activity is to enhance the expertise available in participating countries through training programmes, both short-term (training in routine data analysis and maintenance of tidal installations) and long-term (graduate studies in physical oceanography). In particular, the workshop recommended organizing of a “hands-on” training workshop where the participants will be trained, by experts from different sea-level centres, in microcomputer-based analysis of sea-level data.

The proposal to organize the hands-on training workhop was discussed during the Fourth Session of the IOC Group of Experts on the Global Sea Level Observing System (GE-GLOSS), Bordeaux, France, 31 January - 3 February 1995. GE-GLOSS supported this proposal and helped in prescribing syllabus and programme of the workshop (Annexes I and II). GE-GLOSS also requested IOC to provide financial support for the Training Workshop. IOC accepted this request.

CMAS or a supporting organization from each participating country was asked to nominate a scientist to attend the workshop. IOC, in consultation with GE-GLOSS, invited the nominees to participate in the workshop. IOC, also in consultation with GE-GLOSS, decided on the faculty for the Workshop. The list of nominees and faculty members, is given in Annex III.

IOC accepted an invitation from the Department of Ocean Development (Government of India), New Delhi, to host the hands-on training workshop at the Geodetic & Research Branch, Survey of India, Dehra Dun, India. The Department of Ocean Development also provided financial support towards local organization of the workshop. A National Co-ordination Committee set up by the Department of Ocean Development, New Delhi and a Local Organizing Committee at the Survey of India, Dehra Dun, (see Annex IV) looked after the organization of the workshop.

IOC decided that in view of the major role played by GLOSS in this workshop and because of the importance of the Pilot Activity to the evolution of the Global Ocean Observing System (GOOS), the workshop will be called **GLOSS-GOOS Training Workshop on Sea-Level Data Analysis.**

2. WORKSHOP PROGRAMME

The main body of the Workshop consisted of the following four components: lectures, hands-on training, discussion on activities of CMAS in different countries, and video presentations. In addition, an informal gathering on the first day set the stage for the Workshop, and there was a formal concluding ceremony on the last day. The Workshop programme is outlined in Annex I. Given below is a brief description of the proceedings of the Workshop.

2.1 REGISTRATION AND INFORMAL GET-TOGETHER

Following registration, Dr. Satish Shetye welcomed the participants on behalf of the IOC and provided an overview of **the IOC-UNEP-WMO Pilot Activity on Sea-Level Changes and Associated Coastal Impacts,** genesis of the **GLOSS-GOOSS Training Workshop on Sea-Level Data Analysis,** and the Workshop programme. Brig. B.S. Rajal then welcomed the participants to the campus of the Geodetic & Research Branch, Survey of India, and described the arrangements that have been made to conduct the Workshop.

2.2 LECTURES

2.2.1 Lecture by Dr. T.S. Murty - Introduction to the sea-level problem

Sea-level changes can be slow and spread over a long time (secular), eustatic or eperiogenic (due to land movement). Since the end of the last ice age, seven to eight thousand years ago, significant sea-level changes have been occurring through the glacial rebound process. However, this has slowed down now and other processes - atmospheric and oceanic response to human intervention, for example - need to be considered for understanding global sea-level changes. It is not enough to have a single value for the whole globe. Since many of the effects are local, sea-level measurements using very precise acoustic gauges (precision of the order of one millimeter) will help to detect any accelerated sea-level rise sooner than with the use of traditional tide gauges whose precision is of the order of a centimeter.

2.2.2 Lecture by Dr. T.S. Murty - Introduction to the theory of long gravity wave.

In this lecture the nature of waves generally found in the oceans was first outlined. Then, importance of surface gravity waves in oceanic processes with periods ranging from a few hours to a day or two were discussed. Particular attention was given to long gravity waves in which wave length is much greater than depth of water over which they travel. Characteristics of linear (wave amplitude is much smaller than water depth) long gravity waves were highlighted.

2.2.3 Lecture by Dr. T.S. Murty - Common elements between various types of long gravity waves.

In the ocean wave spectrum wind waves occupy the region with highest frequency (except for acoustic waves). Tides, storm surges and tsunamis fall in this frequency range and are all long surface gravity waves. Their forcing mechanisms, however, differ from one another. Of the three, tsunamis have the shortest periods. Shallow water wave equation can be used to model the three waves. Though interaction between tide and surge can be important, interaction between tide and tsunami is not significant.

2.2.4 Lecture by Brig. B.S. Rajal - Chart datum, local levelling and related issues.

This lecture discussed procedures that are commonly followed in establishing chart datum and techniques used in local levelling.

2.2.5 Lecture by Dr. T.S. Murty - Tsunami: theory and practice.

Tsunamis are generated by under-ocean earthquakes, volcanic eruptions in the ocean, submarine landslides and man-made explosions of sufficiently large magnitude. However, earthquakes are the main cause of tsunamis. Globally, most tsunamis occur in the Pacific Ocean, with some activity in the Indian Ocean and Mediterranean Sea, and occasional occurrence in the Atlantic. Since 1960s, under the auspices of the IOC, a tsunami warning system has been operating for the Pacific Ocean. At its recent meeting in Tahiti, the IOC/ICG Group of Experts endorsed a tsunami warning system for the Indian Ocean. The National Tidal Facility in Australia, along with a few other agencies in Australia, is developing such a system.

2.2.6 Lecture by Dr. T.S. Murty - Storm surges: theory.

Storm surges occur due to atmospheric pressure field and tangential wind stress associated with traveling weather systems such as tropical and extra-tropical cyclones. Till recently, the computer models to simulate storm surges were based on finite-difference models with square of rectangular grids. These had difficulty resolving coastline features with sufficient detail. Some recent models developed by the National Tidal Facility in Australia, and some other groups, use irregular triangular grids in the finite element framework. However, such models arc very complex and not user-friendly.

2.2.7 Lecture by Dr. T.S. Murty - Storm surges: practice.

In storm surge prediction, computation of the total water level requires inclusion of the tide, the surge, the tide-surge interaction and the set-up due to wind wawes. It is not the peak surge alone that is important; stage of the tide with respect to arrival of the surge also has to be considered. Even though the usually available tidal prediction and tide-tables arc adequate for the normal navigational needs, they are not sufficient for handling storm surges. The lecture discussed measures that must be taken for effective storm surge warning system required in situations that need evacuation of people.

2.2.8 Lecture by Dr. T.S. Murty - Sea-level and integrated coastal zone management.

The issue of sea-level and greenhouse effect in the context of integrated coastal zone management was discussed. It was shown how difficult it is to obtain a definition of the coastal zone which is acceptable to all involved. Using Australia as an example, detailed discussion was made of the greenhouse effect, sea-level rise, El-Niño, coastal erosion, and salt water intrusion into coastal aquifers. Methods were outlined On how to study all these diverse phenomena and then combine the analyses into an integrated coastal zone management plan.

2.2.9 Lecture by Dr. Philip Woodworth - Status of global sea-level networks and datasets

This lecture discussed the status of the global sea-level datasets as represented by the Permanent Service for Mean Sea-1evel (PSMSL) dataset. The two main deficiencies of this dataset are (i) the unequal geographical distribution, and (ii) the fact that it reflects relative sea-levels, i.e. relative to land level, which might also change with time. Point (i) is being addressed through the development of GLOSS. GLOSS status was reviewed, especially for the Indian Ocean region. Methods for acquiring sea-level data were presented. Point (ii) concerns the development of the IGS (International GPS Service for Geodynamics) global GPS network which will eventually provide datasets of vertical land movement, which will therefore be merged with the PSMSL sea-level data.

2.2.10 Lecture by Dr. Philip Woodworth - Global sea-level change.

This lecture presented recent findings of the Intergovernmental Panel on Climate Change (IPCC) on best estimates of past, and possible future, global sea-level changes.

2.2.11 Lecture by Dr. Philip Woodworth - Satellite radar altimetry.

This lecture described basic concepts of' geodesy, with particular regard to how the mean sea surface is different from the geoid, and how it relates to ocean circulation studies.

2.2.12 Lecture by Dr. Satish Shetye - Features of large-scale circulation seen in PSMSI, monthly mean data from the North Indian ocean.

The annual cycle of winds over the North Indian Ocean is dominated by the monsoons. In response to these winds, the near surface circulation in the ocean exhibits a distinct annual cycle, signatures of which are expected to be seen in at least some of the PSMSL monthly-mean sea-level data (river stations excluded). In this lecture the annual cycles of monthly-mean wind-stress and monthly mean surface currents (as seen in ship-drifts) were reviewed. The annual cycle of sea-level as seen in the PSMSL data was then summarized. Using a reduced-gravity model of the North Indian Ocean, it was shown that many of the PSMSL stations north of the equator show sea-level variability which is consistent with that seen in the model. Likely causes of departures between the model and observed sea-levels were discussed. Possible strategies in future modelling studies to reduce these departures were also discussed. This lecture summarized the study that was undertaken in response to a recommendation of the planning workshop at Zanzibar.

2.2.13 Lecture by Brig. B.S. Rajal - Global Positioning System

Changing face of geodesy during the last century was reviewed. Evolution of the Global Positioning System (GPS) during the recent past was summarized and its present state of development was described. Accuracy achievable with instruments available at the present, and their strengths/weaknesses were discussed.

2.3 HANDS-ON TRAINING SESSIONS (HOTS)

Mr. Patrick Caldwell conducted hands-on training during the following sessions:
Saturday 25 November 1995, 09.30-13.00
Sunday 26 November 1995, 09.30-13,00
Monday 27 November 1995, 14.00-17.30
Tuesday 28 November 1995, 14.00-17.30
Wednesday 29 November 1995, 14.00-17.30
Thursday 30 November 1995, 14.00-17.30
Friday 1 December 1995, 11.30-13.00

Mr. Caldwell had, as a part of preparation for the workshop, sent to all trainees copies of sea-level data processing software package developed at the Toga sea-level Centre, University of Hawaii, Honolulu, USA. The trainees were also sent a CD-ROM entitled *Sea-level Data from TOGA Sea-level Centre and the permanent Service for Mean Sea-level* (CD-ROM NODC-42). The trainees were expected to be familiar with the software package and were expected to bring with them at least a year’s data from a station of their interest to analyze during the HOTS.

The HOTS were conducted in the large and well equipped computer room of the *National Tidal Data Centre of the Geodetic & Research Branch, Survey of India.* The computer room had eight IBM PC compatible microcomputers specifically earmarked for the HOTS. These machines, together with peripherals, ensured that the trainees would be able to read and write data from and to floppies, read data from CDS and get hard-copies of outputs. Graphics capabilities were available on all the eight microcomputers. The computer room was also equipped with an overhead projector for use during lectures.

In the first HOTS, copies of the document *Sea-level Data Processing Software on IBM PC Compatible Microcomputers* (see Annex II) were distributed to the participants. The document serves as user’s manual to the software package for sea-level analysis. In his introductory talk, Mr. Caldwell discussed in detail the contents of the manual. Following this, each participant proceeded to work under Mr. Caldwell's guidance on analysis of data from a station of his choice.

In the subsequent HOTS, hands-on practice at analyzing sea-level data was alternated with talks by Mr. Caldwell covering the following topics:

(i) Use of tide staff observations for datum control.
(ii) Introduction to the use of PCs, file management, editors, and application of software.
(iii) Tidal analysis and prediction (overview and specific instructions on the use of software).
(iv) Quality control of hourly sea-level data.
(v) Filtering hourly into daily and monthly values.
(vi) Verification of reference level stability, using monthly and daily data.

By the end of the final HOTS each workshop participant had analyzed data from at least (often more) one station to: compute tidal constituents and predict tides; compute residue (de-tided sea-level); compute daily and monthly sea-level.

2.4 DISCUSSION ON ACTIVITIES OF CELLS FOR MONITORING AND ANALYSIS OF SEA-LEVEL (CMAS-ACT)

The Workshop provided an opportunity to emphasize the most important concerns of each CMAS. its organizational set-up, present activities, and future plans. These discussions, which provided a backdrop against which the Workshop. recommendations (see Section 3) were formulated, took place in two parts. In the first part each invited trainee made a presentation on his CMAS. In the second part, future directions that the Pilot Activity should take were discussed.

2.4.1 Presentations by invited trainees

Presentations by the invited trainees took place during the following three sessions:

Wednesday 29 November 1995, 1130-13.00
Thursday 30 November 1995, 11.30-13.00
Friday 1 December 1995, 09.30-11.00

Given below is a brief summary of each presentation.

2.4.1.1 CMAS-Bangladesh: Presentation by Mr. Abdul Matin Mondal

The CMAS is located at the Bangladesh Inland Water Transport Authority (BITWA). Sea-level variation is of major concern in Bangladesh because the vast low-lying areas of the country experience large tidal range, heavy river runoff, and frequent severe storm surges. Combination of the first two together with shallow water waves make tidal prediction difficult. BITWA prepares tide tables for 17 stations in Bangladesh. TO improve prediction capabilities, there needs to be a good gauge, say Seaframe, at St. Martin Island, in the south-eastern part of the country and another at Hiron Point in the west, together with a series of pelagic tidal measurements at 35 m depth contour. There are no firm plans yet to establish such a network. The CMAS would very much like to enhance its capabilities in storm surge prediction.

2.4.1.2 CMAS-India: Presentation by Mr. Lalita Prasad

The CMAS is located at the Geodetic & Research Branch, Survey of India, Dehra Dun, which is responsible for operating a network of 24 gauges around India, and for publication of the Indian Tide Table for 76 ports. Another Tide Table is prepared for Hugli River. G&RB also holds all data collected since 1877. supplies monthly mean sea-levels of all functional Indian Ports to the PSMSL. Besides the IOC-UNEP-WMO Pilot Activity, G&RB, participates in national programmes on sea-level studies. Together with scientists of the National Institute of Oceanography, Goa, this CMAS is involved in research related to: mathematical modelling of tidal circulation on the shelf region of India; and analysis and theory of de-tided sea-level along the Indian coast.

2.4.1.3 CMAS-Kenya: Presentation by Mr. Charles Magori

A gauge functioned during 1933-76 at the Kilindini harbour, Mombasa. However, few data are available from this gauge at the present. Tidal prediction at this harbour is presently based on a year's data collected in 1975-76 by a team from the PSMSL. At present, there are two operational stations: Lamu (an island close to the equator) and Mombasa. The CMAS is hopeful that these data will now be used for tidal prediction. The CMAS is also hopeful that more collaborative efforts with institutions of the countries of the Indian Ocean region will help to enhance its capabilities in application of sea-level data to study physical oceanography of the region.

2.4.1.4 CMAS-Madagascar: Presentation by Mr. N.T. Razakafoniaina

The network of sea-level measurements in Madagascar consists of three float-type tide gauges located in Nosy-Be, Fort-Dauphin, and Tuleen. The Department d'Océanographie Physique et Chimique of the Centre National de Recherches Océanographiques has been designated as the CMAS and looks after collection of tide-gauge data. Within the framework of the IOC-UNEP-WMO Pilot Activity, the CMAS has started collection of oceanographic and meteorological data in the vicinity of the Nosy-Be tide gauge. A data bank has been established to store these data together with sea-level data. The data bank also stores historical data. CMAS has been involved in analysis of these data. A well defined seasonal signal is present at Nosy-Be with high during the Northeast Monsoon and low during the Southwest Monsoon. The future plans of the CMAS are: (i) Upgrade the tide-gauges to improve data quality; (ii) Undertake more sophisticated analysis of the data; (iii) Acquire skills for modelling of tidal circulation around Nosy-Be; (iv) Install a new tide-gauge in Temoteve, in middle portion of eastern Madagascar, where there is considerable concern about coastal erosion. CMAS-Madagascar will very highly appreciate any co-operation received from other countries/agencies towards development of tidal circulation models for the coastal areas of Madagascar.

2.4.1.5 CMAS-Maldives: Presentation by Mr. Ahmed Saleem

The Republic of Maldives is an archipelago of approximately 2000 islands. Average area of an island is less than a quarter of a square kilometre and average height is barely a meter above sea-level. These characteristics make the country highly vulnerable to any sea-level rise due to global warming. Such a rise would lead to, (i) substantial loss of land and property, (ii) landward movement of fresh-salt water interface resulting in decrease in size of the lens of aquifer of the islands, (iii) accelerate coastal erosion. Concerns such as these have prompted Maldives to participate in programmes that involve study of sea-level. There are three TOGA tide-gauges in the Maldives. The responsibility for these gauges rests with the Department of Meteorology of the Ministry of Planning, Human Resources and Environment. At present, CMAS-Maldives is a part of the Marine Research Section of the Ministry of Fisheries and Agriculture, and the emphasis is on acquiring skills for: analysis (determination of tidal constituents and prediction), maintenance of gauges, and datum control.

2.4.1.6 CMAS-Malaysia: Presentation by Mr. The Seug Hoe

The CMAS is located at the Department of Survey and Mapping, Malaysia, which has since 1983 set up a network of 17 stations. This network has now produced a data set with 9 to 12 years record at each station, with only 0.9-5.7% missing observations. The data are processed to publish two publications every year: Record of tidal Observations, and Tidal Prediction Table. Hourly tidal data are available for anyone internationally. The CMAS is very much interested to see that these data are put to use to derive useful inferences or to understand physical oceanography of the region. In this connection the CMAS welcomes collaborative programmes. There are also plans to enhance in-house expertise to take up such problems. There is also a proposal to replace during 1996-2000 older gauges with new instruments.

2.4.1.7 CMAS-Mauritius: Presentation by Mr. S. Ragoonaden

Sea-1evel station on the islands of Mauritius and Rodrigues have float-type gauges and have been operating since 1986. A bubbler gauge installed at Agalega recorded data for only three months before it was destroyed by heavy swells in March 1988. In 1992 the stations at Mauritius and Rodrigues have been transmitting data to TOGA Sea-Level Center (TSLC) via satellite. In addition, hard copies of hourly values are sent to TSLC and monthly values arc sent to PSMSL. The Mauritius Meteorological Service, where the CMAS is located, uses TSLC software to predict sea-level. In addition, sea-level data have been analyzed to study various aspects of variability (TOGA Newsletter, 1993; Report of the Zanzibar workshop, 1994). The CMAS now plans to enhance the scope of analysis to include studies on the link between the variability seen at the two gauges to physical processes in the surrounding ocean.

2.4.1.8 CMAS-Tanzania: Presentation by Mr.O.U. Mwaipopo

The CMAS has been involved with two gauge sites in Tanzania: Dar-es-Salaam harbour and Zanzibar harbour. The former was damaged in 1991 whereas the latter has been workin well for over a decade. There arc plans to repair the gauge at Dar-es-Salaam. It is also hoped that tide-gauges will be installed at Mtwara and Tanzania. There arc plans to take up analysis of data to understand the factors that control the observed variability. Interaction with other institutions of the other Indian Ocean countries will be very helpful to take Up more sophisticated analysis or modelling studies.

24.2 Future Directions of the CMAS

When the Pilot Activity was formulated, it was intended that as a first step, each CMAS participating in the Activity would acquire (if it did not have it already) the capability to predict tides in the region of its interest. This Workshop fulfills this objective and hence marks an important landmark in the development of the Activity.

It is important to sustain this momentum. To achieve this goal, it is necessary for each CMAS to have well defined research goals, however modest they might be. The discussion during this session was oriented towards defining what these research goals might be. Dr. Philip Woodworth was requested to launch this discussion by giving his list of what the research goals might be, based on the presentations made by the invited trainees. Dr. Woodworth's presentation was followed by responses from trainees and faculty members. Given below is a summary of the research goals that emerged from this discussion as both feasible and worthwhile:

(i) Each CMAS should compile tidal constants in its region of interest. These would then serve as inputs to regional tide modelling, and/or for comparison with global tidal models that are now widely available. Such efforts would help in estimation of tidal currents which in turn will be important input for coastal process studies, offshore development schemes, etc.

(ii) The North Indian Ocean offers some regions with special problems. An example is Bangladesh, where tides are strongly influenced by shallow water constituents and river runoff. Developing schemes for accurate day-to-day sea-level variation is a challenging research problem.

(iii) With approximately 5-year long data record referenced to the same datum, it is possible to take up extreme level analysis to estimate, for example, 100 year return probabilities. Malaysia, which during the last few years has generated an excellent sea-level data set is a prime example for taking up such studies. Other CMAS with similar data could take up such studies too.

(iv) A peculiarity of the North Indian Ocean is its seasonal variation. Occurrence of the monsoons is a primary cause of this variability. Seasonal signature is also seen in sea-level records. The factors (air pressure, winds, temperature/salinity changes, ocean currents, runoff, etc.) that cause the seasonal variation in sea-level, need to be studied. Superimposed on the seasonal variability are higher (periods 30-60 days) and lower frequency oscillations (including secular trends). Mechanisms that lead to this variability need to be established too.

(v) Study of sea-level records could lead to establishment of “indices” of different aspects of ocean circulation (strength of currents, intensity of upwelling, etc). Such studies, together with mathematical models of circulation in the North Indian Ocean would help to piece together dynamics of the circulation in the Indian Ocean. It could also lead to development of a scheme to monitor the circulation using a network of sea-level measuring stations. Altimeter data would complement such studies.

(vi) The Survey of India, the oldest organization involved in sea-level data collection in the North Indian Ocean, holds a wealth of very old sea-level records not only from India, but also from surrounding countries, like Burma and Sri Lanka. Publishing documentation on these records would be a very worthwhile effort for sea-level data archaeology of this region.

(vii) Should there be an Indian regional sea-level network? This question appears to be at the back of the mind of everyone associated with the Pilot Activity. Dr. T.S. Murty has mooted the possibility of an Indian Ocean on-line network to monitor evolution of storm surges and tsunamis. Such a network would be very useful for development of a tsunami/storm surge warning system. It may be noted that the North Indian Ocean, especially Bay of Bengal has experienced some of the most devastating storm surges.

It is heartening to note that some of the CMAS have already begun working on some of the research areas listed abowe. There are others who are enthusiastic towards taking up research, but lack the necessary expertise. To develop this expertise it is necessary to initiate training of the scientists associated with a CMAS at Universities and research Institutions involved in sea-level studies. IOC, UNEP and WMO, who have initiated the Pilot Activity, need to provide resources for such training.

The Session concluded with the hope that in 1997/98 the scientists associated with the Pilot Activity will meet to present results of some of the research problems outlined above.

2.5 VIDEO PRESENTATIONS

All video presentations were conducted by Dr. T.S. Murty. He introduced each video and fielded questions after screening. The following four videos were screened.

2.5.1 Video - Tidal Theory (25 min., produced for the Royal Australian Navy)

In this video, the astronomical forces that cause tides in the world’s oceans are illustrated. It is shown that the Sun's tide-generation force is about 46% of that of the Moon. The concept of tide-generating force is explained. Features of diurnal, semi-diurnal and long-period tides is explained. Generation of shallow-water constituents is discussed. Amplification of tides on continental shelves, nature of tidal currents, and formation of tidal bores in rivers arc illustrated.

2.5.2 Video - Greenhouse effect and its impact on sea-level (8.5 min., produced for the National Greenhouse Advisory Committee of Australia)

This video argues that an accelerated sea-level rise due to greenhouse gases could be detected earlier with the use of precision (1 mm) sea-level gauges than with conventional gauges with lesser precision (approximately 1 cm). Since any tide-gauge measure only relative, not absolute, sea-level, precise geodetic measurements have to be made together with a programme of sea-level measurements. Though satellite altimetry can provide an overall picture of the sea-level for an ocean basin, it is highly unlikely that it can catch the precision of the new generation acoustic gauges, at least in the foreseeable future.

2.5.3 Video - Hydrographic surveying by LADS (10 min, produced for the LADS Corporation, Australia)

One of the problems facing construction of numerical models for tides, storm surges and tsunamis is lack of detailed bathyrnetry. The Vision Systems Inc., Australia, has successfully developed a system using lasers to carry out hydrographic surveys from aircraft instead of from ships. Airborne surveys can be carried out much faster and bear the promise of providing quickly bathymetry in shallow areas needed for numerical modelling of tides, surges, etc. At the present, lack of such data is hampering progress in many vulnerable areas.

2.5.4 Video - Tsunamis (90 min., produced for the International Tsunami Information Centre (IOC), Honolulu, USA)

This video illustrates many features of: earthquakes in ocean basins; the tsunamis that are generated by such earthquakes; tsunami warning systems; and, measures generally taken for protection against tsunamis. Sociological aspects associated with tsunamis are also discussed. Ongoing research to study tsunamis is outlined. Dynamics associated with generation of tsunamis, their propagation over deep ocean, coastal amplification, in particular resonance amplification, are illustrated.

2.6 CONCLUDING CEREMONY

The concluding ceremony was held in the conference room of the Hotel Madhuban. The chief guest at the function was Dr. A.E. Muthunayagam, Secretary, Department of Ocean Development (Government of India), New Delhi. The ceremony was presided over by Maj. Gen. S.P. Mehta, Surveyor General of India. The invitees included, distinguished officials of the Survey of India and the Naval Hydrographic Office, Dehra Dun. Brig. B. S. Rajal welcomed the gathering and provided an overview of genesis of the Workshop. In his presidential address, Maj. Gen. Mehta pointed out that study of tides began at the Survey of India in the year 1877. He emphasized the expanding role of sea-level study from being only an aid to shipping to an indicator of global climate change. Maj. Gen. Mehta concluded his speech by suggesting that countries of the Indian Ocean ought to examine the possibility of setting up an on-line regional sea-level network that can keep track of this ocean pulse. The Chief Guest Dr. Muthunayagam highlighted the role that sea-level monitoring has been playing in global research programmes such as Tropical Ocean and Global Atmosphere (TOGA) and World Ocean Circulation Experiment (WOCE). He pointed out that, the Department of Ocean Development has during the last few years actively supported programmes for improving India's capabilities to monitor and analyze sea-level data from the region, and that the Department will very much encourage any proposal to consolidate collaborative programmes on sea-level studies amongst IOC countries of the Indian Ocean. Dr. Philip Woodworth, speaking on behalf of the IOC, the Group of Experts on GLOSS, and the Workshop Faculty, expressed his thanks to the Department of Ocean Development and the Survey of India for making the Workshop a reality. Mr. Abdul Matin Mondal, one of the eight trainees, expressed his satisfaction for having been given the opportunity to learn new techniques of sea-level data analysis. He complemented the organizers for making sure that adequate facilities became available to conduct the hands-on sessions. Dr. Satish Shetye, speaking on behalf of the National Organizing Committee of the Workshop, proposed a vote of thanks.

3. RECOMMENDATIONS

The following recommendations are based on the views expressed by the invited trainees and the members of faculty during different components of the Workshop programme, particularly during discussions on activities of CMAS:

(i) **Noting with satisfaction** that this Workshop marks completion of a goal set by the Pilot Activity, namely to enable each CMAS to acquire expertise in modern techniques of basic sea-level data analysis and tidal prediction, it is recommended that each CMAS should sustain this progress by defining for itself definite research objectives for the next few years and pursuing these objectives either independently or in collaboration with others.

(ii) **Noting** that though many CMAS are enthusiastic about taking up research problems related to sea-level variability, they are severely constrained by lack of expertise in this area. **It is felt** that these CMAS would benefit by setting up collaborative programmes with Universities and Institutions where expertise is available. Research of interest to a CMAS could then be conducted as a graduate/doctoral thesis research under the supervision of a suitable faculty member at these universities/institutions. **It is recommended** that the IOC support such programmes either independently or together with UNEP and WMO, the two co-sponsors of the Pilot Activity in the Indian Ocean.

(iii) **Noting** that this Workshop, besides providing training in sea-level data analysis, also provided a highly desirable venue for interaction amongst CMAS and between CMAS and other organizations from different parts of the world, **it is recommended** that IOC support a similar meeting in 1997-98 to review progress made on different research problems identified during this Workshop.

ANNEX I

WORKSHOP PROGRAMME AND TIMETABLE

Tuesday 21 November 1995

15.00-17.00: Registration and informal get-together of the participants to discuss agenda of the workshop, arrangements, data to be processed during "hands-on" training sessions, etc.

Wednesday 22 November 1995

09.30-11.00: Lecture by Dr. T.S. Murty - Introduction to the sea-level problem
11.30-13.00: Video on "Tidal Theory" (25 min., produced for the Royal Australian Navy)
14.00-15.30: Lecture by Dr. T.S. Murty - Introduction to the theory of long gravity wave.
16.00-17.30: Lecture by Dr. T.S. Murty - Common elements between various types of long gravity waves.

Thursday 23 November 1995

09.30-11.00: Lecture by Brig. B.S. Rajal - Chart datum, local levelling and related issues.
11.30-13.00: Lecture by Dr. T.S. Murty - Tsunami: theory and practice.
14.00-15.30: Lecture by Dr. T.S. Murty - Storm surges: theory.
16.00-17.30: Lecture by Dr. T.S. Murty - Storm surges: practice.

Friday 24 November 199.5

11.30-12.50: Video presentation - Greenhouse effect and its impact on sea level (8.5 min., produced for the National Greenhouse Advisory Committee of Australia)
12.50-13.00: Video presentation - Hydrographic surveying by LADS (10 rein, produced for the LADS Corporation, Australia)
14.00-15.30: Video presentation - Tsunamis (90 min., produced for the International Tsunami Information Centre (IOC), Honolulu, USA)
16.00-17.30: Lecture by Dr. T.S. Murty - Sea-level and integrated coastal zone management.

Saturday 25 November 1995

09.30-13.00: Hands-On Training Sessions (HOTS) conducted by Mr. Patrick Caldwell
14.00-17.30: HOTS conducted by Mr. Patrick Caldwell

Sunday 26 November 1995

09.30-1 3.00: HOTS conducted by Mr. Patrick Caldwell

Monday 27 ***November*** 1995

09.30-11.00: Lecture by Dr. Philip Woodworth - Status of global sea-level networks and datasets.
11.30-13.00: Lecture by Dr. Philip Woodworth - Global sea-level change.
14.00-17.30: HOTS conducted by Mr. Patrick Caldwell.

Tuesday 28 November 1995

09.30-11.00: Lecture by Dr. Philip Woodworth - Satellite radar altimetry.
11.30-13.00: Lecture by Dr. Satish Shetye - Features of large-scale circulation seen in PSMS monthly-mean data from the North Indian Ocean.
14.00-17.30: HOTS conducted by Mr. Patrick Caldwell.

Wednesday 29 November 1995

09.30-11 .00: Lecture by Dr. Philip Woodworth -
11.30-13.00: Presentations on Activities of Cells for Monitoring and Analysis of Sea-level.
14.00-17.30: HOTS conducted by Mr. Patrick Caldwell.

Thursday 30 November 1995

09.30-11 .00: Lecture by Brig. B.S. Rajal - Evolution of geodesy and Global Positioning System.
11.30-13.00: Presentations on Activities of Cells for Monitoring and Analysis of Sea-level.
14.00-17.30: HOTS conducted by Mr. Patrick Caldwell.

Friday 1 December 1995

09.30-11 .00: Discussion on future activities of Cells for Monitoring and Analysis of Sea-level and finalization of Workshop recommendations.
11.30-13.00: HOTS conducted by Mr. Patrick Caldwell.
15.30-17.00: Concluding Session

ANNEX II

LIST OF COURSE MATERIALS

The following documents were either distributed or made available to the participants during the workshop:

1. Caldwell, P.C. (1995) *Sea Level Data Processing Software on IBM PC Compatible Microcomputers,* TOGA Sea Level Centre, University of Hawaii, USA (Manual and software on floppies)

2. *Sea Level Data from TOGA Sea Level Centre and the Permanent Service for Mean Sea Level,* (CD-ROM NODC-42), National Oceanographic Data Centre, USA..

3. *Wales, tides and shallow-water processes,* prepared by an Open University Course Team (1989), Pergamon in association with the Open University, UK, 187 pp.

4. Pugh D.T. 1987: *Tides, surges and mean sea-level: a handbook for engineers and scientists,* Willey, Chichester, 472 pp.

5. *Manual on Sea-Level Measurments and Interpretation, Volume 1- Basic Procedures,* IOC Manuals and Guides 14 (1985) UNESCO, 83 pp.

6. *Manual on Sea-Level Measurments and Interpretation, Volume 2- Emerging Technologies,* IOC Manuals and Guides 14 (1985) UNESCO, 72 pp.

7. *Joint IAPSO-IOC Workshop on Sea Level Measurments and Quality Control,* Paris, 12-13 October 1992, IOC Workshop Report No. 81, UNESCO, 167 pp.

8. *IOC-UNEP-WMO Pilot Activity on Sea-Level Changes and Associated Coastal Impacts - draft action plan for implementation in the Indian Ocean,* 1992, IOC/INF-908, UNESCO.

9. *IOC-UNEP-WMO-SAREC Planning Workshop on an Integrated Approach to Coastal Erosion, Sea Level Changes and their Impacts, Zanzibar; United Republic of Tanzania, 17-21 January 1994, Submitted Papers-2: Sea Level,* IOC Workshop Report No. 96- Supplement 2, UNESCO, pp 104.

ANNEX III

LIST OF PARTICIPANTS

I. **INVITED TRAINEES**

BANGLADESH

Mr. Abdul Matin **Mondal**
Senior Deputy Director(Tide)
Department of Hydrography
Bangladesh Inland Water Transport
Authority (BIWTA) BHABAN
Ministry of Shipping
141-143, Notijheel C/A
Dhaka - 1000
Bangladesh
Tel: 880-2-36151-55/35042/46057-60
Fax: 880-2-231072
Tlx: 642787 BINTA BJ

I N D I A

Lalita **Prasad**
National Tidal Data centre
C/O No, 68 (Tidal) Party
Geodetic & Research Branch
Survey of India,
17 - E.C. Road
Dehra Dun 248001
India
Tel: (91)(135) 24528
Fax: (91)(135) 585218

KENYA

Mr. Charles **Magori**
Kenya Marine & Fisheries Research Institute
(KMFRI)
P.O. Box 81651
Mombasa
Kenya
Tel: (254-11) 475574/79
Fax: (254-11) 472215

MADAGASCAR

Mr. N. T. **Razakafoniaina**
Département d'Océanographic
Physique et Chimique
Centre National de Recherches
Océanographiques (CNRO)
B.P. 68 (207), Nosy Bé
Madagascar
Tel: (261) 61373
Cable: OCEANNOSYBE

MALAYSIA

Mr. The Seng **Hoe**
Department of Survey & Mapping Malaysia
Jalan Semarak
50578 Kuala Lumpur
Malaysia
Tel: (60)(3) 292-53-1 1/292-54-90
Fax : +(60)(3) 293-40-84
Tlx : SURMAP MA 28148
Cable: UKURPETA

MALDIVES (Republic of

Mr. Ahmed **Saleem**
Environment Research Unit
MPHRE
Ghazee Building
Male 20-05
Republic of Maldives
Tel: (960) 322286
Fax: (960) 327351

MAURITIUS

Mr. S. **Ragoonanden**
Scientist, Meteorological Service
St. Paul Road
Vacoas
Mauritius
Tel: (230) 686-10-31/32
Fax: (230) 686-10-33
Tlx: 4722 METEO IW

TANZANIA (United Republic of

Mr. O. U. **Mwaipopo**
Institute of Marine Sciences
University of Dar-es-Salaam
P.O. Box 668
Zanzibar
Tanzania
Tel: (255)(54) 02120/00741
Fax: (255)(54) 33050/32128/32159
Cable: UNIMARS ZANZIBAR

II. INVITED LECTURERS

Mr. Patrick C. **Caldwell**
TOGA Sea-Level Centre
University of Hawaii at Manoa
1000 Pope Road,
Honolulu, Hawaii 96822
USA
Tel: (1)(808) 948 76 33
Fax: (1)(808) 956 23 52
Tlx: 650-247-8678
Internet: caldwell@edu.hawaii.soest.hokulea

Dr. Tad S. **Murty**
Director
National Tidal Facility
Flinders University of South Australia
GPO Box : 2100
South Australia 5001
AUSTRALIA
Tel: (618) 201 7524/201 7523 (Direct)
(618) 201 7531 (standard)
Fax: (618) 201 7523
e-mail : motid@pippin.cc.flinders.edu.au

Brig. B.S. **Rajal**
Director
Geodetic & Research Branch
Survey of India
P.O. Box No. 77
17 E.C. Road
Dehra Dun 248001
INDIA
Tel: (91)(135) 24528
Fax: (91)(135) 27623
Tlx: 585 211 PGO IN

Dr. Satish **Shetye**
Physical Oceanographic Division
National Institute of Oceanography
Doria Paula, Goa 403004
INDIA
Tel: (91 832) 22 13 22/22 62 53
Fax: (91 832) 22 33 40/22 13 60
E-mail: Shetye@bcgoa.ernet.in

Dr. Philip **Woodworth**
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead, Merseyside L437RA
UNITED KINGDOM
Tel : (44)(151) 653 8633
Fax : (44)(151) 653 6269
Internet : plw@pol.ac.uk

ANNEX IV

NATIONAL CO-ORDINATION COMMITTEE

Mr. B.N. Krishnamurthy Director, Department of Ocean Development Government of India, New Delhi	*Chairman*
Dr. E. Desa Director, National Institute of Oceanography Goa	*Member*
Brig. B.S. Rajal Director, Geodetic & Research Branch Survey of India, Dehra Dun	*Member*
Capt. M.K. Thomas Naval Hydrographic Office, Dehra Dun	*Member*
Dr. Satish R. Shetye Scientist, National Institute of Oceanography Goa	*Member*
Director Directorate of Naval Oceanography and Meteorology Naval Headquarters, New Delhi	*Member*
Representative Department of Science & Technology Government of India, New Delhi	*Member*
Dr. V.N. Sanjeevan Department of Ocean Development Government of India, New Delhi	*Special Invitee*

LOCAL ORGANIZING COMMITTEE (Geodetic & Research Branch, Survey of India, Dehra Dun):

Brig. B. S. Rajal	*Chairman*
Lt. Col. J.S. Grover	*Organizing Secretary*
Brig. R.P. Iyer	*Member*
Mr. S.L. Dhingra	*Member*
Maj. V.P. Srivastava	*Member*
Mr. Lalita Prasad	*Member*