Intergovernmental Oceanographic Commission
Training Course Reports

51

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

Department of Oceanography
University of Cape Town

South Africa
16–27 November 1998

UNESCO

IOC Training Course Report No. 51
Paris, 20 July 1999
English only

SC-99/WS/47

TABLE OF CONTENTS

SUMMARY REPORT

ANNEXES

I. INTRODUCTION

The IOC/GLOSS-GOOS Training Workshop on Sea-Level Data Analysis was held at the University of Cape Town, South Africa from 16-27 November 1998, under the auspices of the Intergovernmental Oceanographic Commission (IOC) and the University of Cape Town (UCT).

The primary objectives of the Workshop were:

(i) to improve understanding of the tidal and meteorological processes that control sea level at sites along the coasts of Africa, south of the Sahara;

(ii) to enhance the capabilities of the coastal countries to monitor, analyse and interpret sea-level data;

(iii) to emphasise the added value to be gained from regional cooperation;

(iv) to build on earlier initiatives of GLOSS, GOOS and the IOC in these respects.

Invitations were sent out to all relevant GLOSS contacts, announcing the Workshop and applications for attendance at the Workshop were received from 35 potential participants. The choice of successful applicants was made according to several criteria:

(i) to provide a representative spread of participants from the coastal states and island nations of Africa south of the Sahara;

(ii) to build up the number of competent African scientists familiar with sea-level activities;

(iii) to try to fill gaps in the GLOSS network, particularly at sites with historically long records which have now lapsed;

(iv) to remain within the budgetary constraints available for the Workshop.

The participants were from Senegal, Côte d'Ivoire, Ghana, Nigeria, Namibia, South Africa, Mozambique, Tanzania, Kenya, Yemen, Mauritius and Brazil, as well as some local participants (see Annex II).

The Workshop benefitted greatly from the involvement of members from the GLOSS Panel of Experts, Dr P. L. Woodworth and Dr T. F. Baker of the Proudman Oceanographic Laboratory in the United Kingdom, and from Ms J. R. Trotte from the IOC GOOS Project Office.

The Workshop was held in the Blue Micro-Laboratory of the Department of Electrical Engineering at the University of Cape Town. Networked personal computers were available to each participant and the formal presentations, discussions and hands-on training sessions took place in the same venue. The organization of air travel, local accommodation and transport was the responsibility of Dr K. Findlay, Manager of the Centre for Marine Studies, whilst the Chairman of the Workshop was Professor Brundrit.

2. WORKSHOP PROGRAMME

The main body of the Workshop was devoted to formal presentations, discussions and hands-on training in sea-level measurements and analysis. In addition, two days of field excursions were undertaken, and a programme of social events took place. The detail of the Workshop Programme can be found in Annex I, whilst a list of course facilities and reference materials can be found in Annex III.

Below is a brief description of the proceedings of the Workshop.

2.1 REGISTRATION

The Workshop commenced on the evening of Sunday, 15 November at All Africa House and the participants were welcomed by the Principal of the University of Cape Town, Dr M. A. A Ramphele. This was followed by registration and a supper of traditional African food.

2.2 OPENING

The participants gathered in the Blue Micro Laboratory at 9.00 a.m. on Monday, 16 November. On behalf of the Intergovernmental Oceanographic Commission (IOC), the Workshop was opened by Ms J. R. Trotte. The Workshop Chairman, Professor Brundrit, outlined the arrangements, facilities and programme for the Workshop and introduced the invited experts: Dr Woodworth and Dr Baker.

2.3 PRESENTATIONS BY PARTICIPANTS

Each participant gave a 15-minute presentation on the sea-level activities in their own country as part of the introductory sessions in the Workshop. Dr P. L. Woodworth of the Permanent Service for Mean Sea Level of the (PSMSL) Proudman Oceanographic Laboratory (UK) gave an overview of the history of sea-level data collection and the instruments that had been used over the years in the GLOSS network. Reference was made to the two volumes on sea-level measurement and interpretation published by the IOC (Manuals and Guides Series No.14, vol. I & II). Synopses of these presentations as provided by the participants follow, in geographical order from west to east.

BRAZIL - (A. da Silva)

A general view of the Brazilian Hydrographic Office Survey and the tide gauge network serving GLOSS was presented. An outline of the Brazilian sea level programme was provided, as well as some of the real problems that still prevail in the country, hindering full participation in GLOSS. Most of these problems are related to the processing and compiling of the tide gauge data sets and the transcription into sea-level data.

The present tide gauge network in Brazil is composed of ten stations along the Brazilian Coast. Some have special importance: Rio Grande is next to an amphidromic point and, because of this, its position will probably be changed in the near future; Ponta da Madeira is now working well and is a good example of a cooperative effort between the Government and the private sector, with Vale do Rio Doce operating and maintaining the tide gauge equipment at the site; Areia Branca, located at Termisa Point, is a salt terminal where a satellite platform for tide gauge observation has been installed; Cananeia, located to the southeast of Sao Paulo, is maintained by the University of Sao Paulo. All the stations maintain a good general performance, but there are problems in coping with the volume of data generated.

SENEGAL - (B. Diaw)

Historical data: 1942-1945, 1952-1953, 1958-1966 from the GLOSS station at Dakar (14°40'N, 17°25'W)

Recent data collected from two gauges:

- one at Dakar maintained by NOAA: 1992-1998, and
- another off Dakar at Goree island maintained by ORSTOM.

Problems

There is confusion about the responsibility for the two gauges, and the relationship to GLOSS. There are also no records in any local data base. The Harbour authorities were supposed to be responsible for the gauge in Dakar harbour, but it is not clear if they are gathering the data locally. Data from the ORSTOM gauge is received directly by satellite. The GLOSS contact person in Senegal should approach them to get more information about this tide gauge. A local data bank needs to be created.

Sea-level data needs for oceanographic applications

The "Centre de Recherches Océanographique de Dakar-Thiaroye" has research programmes using long data series from coastal stations. These data need to be complemented by sea-level data. There is a need to know more about the upwelling mechanism off Senegal and research projects have been initiated to study the heat exchange between ocean and atmosphere, and to study waves, including coastal trapped waves. It is hoped that better coordination will be forthcoming in handling the sea-level data problem so that high quality data series will be available from Senegal soon.

GHANA - (M. Tabil)

Sea-level observations started in Ghana in 1924 in the Takoradi harbour. In 1961, another tide gauge was placed in the Tema harbour to enhance the observations. The results of the observations are sent to PSMSL, Bidston (UK) for analysis and predictions. At the tide gauge sites, there are benchmarks for levelling purposes, that tie sea levels into the national datum system. Presently the two gauges are no longer functioning. An appeal was made to IOC to help Ghana replace the tide gauges to ensure continuity of observations.

SOUTH AFRICA - (M. Thomson)

The South African Naval Hydrographic Office was formed in 1954. Installation of the first of its own KENT float-type gauges followed in 1957, and the operation of certain SA Railways and Harbours gauges appear to have been taken over at about the same time. Occasional additions were made to the original network of KENT gauges using LEA, OTT and SIAP float-type gauges.

Twelve tidal stations were in operation by 1989 but most of the gauges were getting too old to provide reliable data. (Note that two of the original mechanical gauges continue in service in tandem with their modern replacements). At that stage, the EMATEK Division of the CSIR was commissioned to design and construct acoustic Automatic Water Level Recorders (AWLRs) incorporating barometers and temperature sensors. A total of eight were acquired, but they never proved to be a success and, after several years of perseverance, they were abandoned in 1996/97. The exception is the AWLR at Walvis Bay, now in Namibia, which operates successfully and has produced good, accurate datasets for the last two years.

The AWLRs were replaced with ten SRD acoustic gauges which were installed in 1996/97. These have produced continuous datasets but their accuracy is, in many cases, unacceptably variable. To date, this difficulty remains to be resolved and plans are well advanced for the acquisition of a new generation of float-actuated gauges to supplement the existing network.

The Bidston Observatory provided tidal predictions until 1964, at which stage the first South African Tide Tables (for 1965) were issued. These have been issued annually ever since.

MOZAMBIQUE - (V. Dove)

Mozambique is located between 10° 27'S and 26° 52'S latitude and 30°12'E and 40°51'E longitude. There have been twelve float-type tide gauges installed over the years, but only four are operational. They are at Pemba, Nacala, Beira and Maputo. Pemba and Inhambane are part of the GLOSS network. Pemba, GLOSS station number 11, is in the Cabo Delgado province, the northmost province of Mozambique, at the latitude 12°58'S and 40°29'E. It was installed in 1992, but the data from it is available only from 1993. Inhambane, located in the south part of the country at the latitude 23°55'S and 35°30' E, is the GLOSS station number 10. Since its installation in 1993, it worked irregularly during one year and since 1995 is has not been operational. The authority responsible for these tide gauges is INAHINA in Maputo.

TANZANIA - (S. Mahongo)

The network consists of two operational stations at Zanzibar and Dar-es-Salaam. There are also three non-operational tide gauges at Mtwara, Tanga and Pemba. The Zanzibar Station has a Handar encoder data logger with satellite communication. This new tide gauge was installed in 1990, replacing the old Munro IH 109 float gauge (1983-1993). The Dar-es-Salaam station has a mechanical SEBA float gauge, which was installed in 1997. This tide gauge replaced a Leupold and Stevens float gauge (1986-1990) whose stilling well was damaged by a boat. The tide gauge in Mtwara was a Munro IH 109 float-type, which worked from 1959 to 1962. Previously, a Munro IH 40 was in operation from 1956 to 1957. A Munro IH 40 tide gauge in Tanga worked from 1962 to 1966, while that of Pemba (Munro IH 109) was incorrectly installed in 1991 and consequently never worked. Of all these stations, the Zanzibar station has been operating well since 1984.

KENYA - (C. M. Angwenyi)

The first tide gauge in Kenya was installed at Kilindini harbour -Mombasa in 1933. This worked until 1976 but not much data was collected. In 1975/76 a team from PSMSL collected one year of continuous data in the same place. Tidal predictions in Kenya are based on these data. The University of Hawaii donated a tide gauge to KMFRI in 1986. This was installed at Liwatoni harbour in Mombasa and was in operation until it was updated again by a donation from the University of Hawaii. This worked well till the time when the University again donated modern data loggers. These were installed at Mombasa and Lamu Islands. The loggers measure sea level every minute and store the data on diskettes at fifteen minutes interval. The Lamu tide gauge was additionally equipped with a satellite data transfer device to enable real- time access to the data. To date, these tide gauges are working and the data collected is sent to the University of Hawaii for further analysis.

YEMEN - (G. M. Bawazir)

The coastal zone of Yemen stretches over 2600 km. The oceanographic conditions in the Gulf of Aden is influenced by two monsoons during a single year. Yemen has two non-operational GLOSS stations (Aden and Socotra island). Aden is amongst the oldest GLOSS stations, and has reliable monthly sea-level data from 1897-1967.The tide data from 1967-1986 was recorded at Aden port. Presently, these two stations have a shortage of equipment and measuring instruments. The Marine Science Resources and Research Centre in Yemen is obligated to sea-level monitoring. This forms an important contribution to the understanding of seasonal and long-term variations in sea level as a consequence of changes in physical processes which have a direct influence on the biological productivity on this region .

MAURITIUS - (B. Dunputh)

Sea-level measurements have been gathered since 1986 at Port-Louis (Mauritius) by a Stevens floating gauge. This gauge was donated by the university of Hawaii. Surveys carried out confirmed that the tide gauge was stable. The gauge transmits by satellite at fifteen minutes intervals, real-time data to the University of Hawaii for further analysis.

Some preliminary analysis has been done in Mauritius. Results will be discussed in the national report. Apart from the usual variations, different signals have been recorded during cyclone events, tsunami waves (June 1994) and during storm surges. Furthermore, tide predictions obtained from Hawaii are comparable with actual values. Mauritius (and Rodrigues) will continue to monitor sea level in the future and the replacement of tide gauges will be needed.

2.4 LECTURES

2.4.1 Introduction to Sea Level Around Africa - Professor G. B. Brundrit

GLOSS is a global system with a number of elements. Foremost are the GLOSS Core Network, and the special purpose networks such as the Long-Term Network to support climate change, the Altimeter Network to support satellite altimetry, and the Ocean Circulation Network to support ocean transport studies. Each network has its African sector, which will be the concern of the Workshop. However, the detail of the operational stations and the duration of historic data demonstrates a serious deterioration in the situation with respect to the African stations in the GLOSS network. The Training Workshop participants are spread around the entire coast of Africa, south of the Sahara, and are well placed to contribute to improving the operational readiness of the GLOSS network in Africa.

2.4.2 International Programmes of the IOC - Ms Janice R. Trotte

One of IOC's major programmes is the Global Ocean Observing System (GOOS). GOOS is intended to be a permanent global system for observations, modelling and analysis of marine and ocean variables needed to support operational ocean service worldwide. The planning, design and technical definition of GOOS is being developed by advisory panels dealing with: climate; coastal sea; living marine resources; the health of the ocean (i.e. pollution); and marine meteorological and oceanographic services.

A GOOS Initial Observing System (GOOS-IOS) has also been formed from a number of pre-existing observing systems, each of which will continue to serve the group of clients for which it was originally set up. GLOSS is part of GOOS-IOS and it is hoped that the GLOSS station network can be used as the foundation for networks of other oceanographic observations in the GOOS modules.

2.4.3 Introduction to Tidal Analysis - Dr T. F. Baker

Tidal dynamics can be explained through the gravitational interaction of the sun and the earth-moon system. A useful simplification is the consideration of the equilibrium tide on a completely water-covered Earth, for the moon alone and for the sun alone. When both sun and moon are present, constructive and destructive interference can occur which explains the longer period tidal effects. The detail of tidal constituents can be explained through the astronomical constants of the equilibrium tides. The actual ocean tides vary from the equilibrium tides because of the presence of the continents and other local effects. Nevertheless, much of their character remains identical and the details can be determined through tidal analysis.

2.4.4 Sea Level and Climate Change - Dr P. L. Woodworth

Sea-level variability gives an excellent proxy measurement of climate change. Thus, the current concern with estimating the anthropogenic component of climate change through global warming can be assisted from long-term trends in sea level. The causal chain is fairly short and straightforward. Increased production of greenhouse gases in industrial and agricultural activities leads to atmospheric temperature rise. In turn, this heat is trapped in the ocean and expands the height of the water column, causing sea level to rise. There are secondary effects in changes in ocean circulation patterns which are also of interest. The Intergovernmental Panel for Climate Change has sought to provide the best estimates of trends in environmental observations, including sea-level rise. For this to be understandable and consistent conclusions drawn, the effect of global warming has to be separated from the underlying crustal movements (see below). These estimates are valuable to coastal planning authorities worldwide.

2.4.5 Geodetic Networks - Dr T. F. Baker

There are a number of positioning systems available which provide information relative to a geodetic network. These are the Very Long Baseline Interferometry approach, Satellite Laser Ranging and the Global Positioning System. All suffer from the lack of precision in the description of the geoid, which will only be rectified by direct gravity measurements or a dedicated gravity mission on a satellite. Tide gauge absolute height measurements require both relative measurements and crustal measurements. These can be estimated from models of Post Glacial Rebound such as the ICE-3G model of Peltier, or through repeated GPS measurements. Tide gauge benchmarks then link in with the local land levelling network, to enable sea-level rise and ocean circulation variability to be estimated. A series of reports, culminating in the 1997 JPL meeting, have shown how increasing accuracy in GPS measurements has fixed the tide gauges within the International Global Positioning System Geodynamic Service (IGS). In turn, this has enabled the back-calculation of precise satellite orbits.

2.4.6 Satellite Altimetry - Dr P. L. Woodworth

Satellite altimetry provides routine measurements of sea-level height over the global ocean. Since the early and short-lived flight of SeaSat, through the protracted observations of GeoSat to the present much improved instruments aboard TOPEX-Poseidon and the ERS series, much valuable information on sea-level variability has been forthcoming. This has enabled direct links to be made to tide gauges sites, particularly those on oceanic islands. The assimilation of this data into Global Ocean Circulation Models has improved the representativeness of these models and their overall usefulness.

2.4.7 Land Levelling Exercises - Professor C. R. Merry

Careful repeated levelling of tide gauges with respect to tidal benchmarks, and the land levelling system, is important so as to ensure consistent high quality data over a long period of time. This can be achieved using various survey instruments. However, there is much to be gained from using a standard check procedure during the levelling process. These checks were introduced in the presentation, and the participants used them in actual levelling exercises on the university campus. Successes and failures enhanced the learning experience.

2.4.8 Tide Gauge Transcription Software

Several participants took advantage of an invitation to visit the South African Navy Hydrographic Office. This enabled them to see at first hand the tide gauge transcription facilities used for the float gauges still in use. In particular, they were given copies of relevant software.

2.5 HANDS-ON TRAINING SESSIONS

A series of Hands-On Training Sessions (HOTS) took place throughout the duration of the Workshop. These made use of the networked personal computers in the Blue micro-laboratory on which common software was pre-loaded and made available to all participants.

The first HOTS on the afternoon of Monday, 16 November was intended to provide the participants with experience of the local computer network environment. It introduced the E-mail facility used for communication between Workshop participants and presenters, as well as for outside communication. A WWW-based public software package, Tidal Synthesis and Prediction by Dr R. A. Nunes Vaz, with examples of predicted tides world-wide, was used to illustrate the spatial and temporal variation in tides around Africa. The next major portion of HOTS was devoted to the Tidal Analysis Software Kit (TASK-2000) from the Permanent Service for Mean Sea level. This took up the afternoons of Thursday 19 and Friday 20 November. The first step was to introduce the package as a whole through the TASK plotting module to display relevant data sets used as input to and output from the TASK-2000 package. The next step was to become familiar with an entire typical tidal analysis procedure generating constituents and residuals, using sample data provided in the package.

The final HOTS session was spent on the tidal analysis of historic sea-level data from a station in the participant's home country. Typically, this involved recovering a year-long record at an appropriate station from one of the CD-ROMs of historic sea-level data and applying the TASK-2000 package to this data. As well as generating tidal constituents, an assessment of the quality of the historic data was made, and where appropriate, tidal predictions for a series of years were made. This demonstrated the potential of the historic data, emphasised the benefits of extending a record with new high quality data and showed how tidal and sea-level analysis could be used to characterise a coastal site.

2.6 FIELD EXCURSIONS

2.6.1 Simon's Town Day

The first field excursion took place on Wednesday, 18 November. The participants travelled down the coast to Simon's Town where they were the guests of the Institute for Maritime Technology and the South African Navy. The day started with a welcome and brief survey of the activities of the Institute of Maritime Technology by Dr R. van Reenen. The Tidal Superintendent of the Hydrographic Office of the South African Navy, Capt. M. Thomson, then provided a detailed description of the operation of the South African tide gauge network with an emphasis on the various types of instruments that had been used in the network. He paid particular attention to the care needed in the change-over from a network based on stilling wells to one which used acoustic gauges linked and interrogated telephonically. His presentation was followed by a visit to the Simon's Bay tide gauge site in the nearby South African Naval Dockyard. This was particularly instructive as a new acoustic gauge has been fixed next to the old stilling well gauge. The officers responsible for the maintenance of the gauge showed the relevant survey benchmarks, demonstrated the calibrations routinely carried out on the gauges and the Workshop participants were able to see the data logger and remote telecommunication facility at the site. After lunch, the participants were free to explore the historical parts of Simon's Town.

2.6.2 West Coast Day

The second field excursion took place on Tuesday, 24 November. The participants travelled up the West Coast to the north of Cape Town in order to observe tidal currents and evidence of past sea levels above the present. Langebaan Lagoon is some 10 km long with a narrow entrance, where tidal currents can be observed at close hand. Ms M. Krug is studying the dynamics of these currents at this location as part of her

M.Sc degree in the Department of Oceanography at the University of Cape Town. She was able to give the participants some key insights into the important processes at play and to relate these to the theory presented earlier in the Workshop. The group then moved further north to the rocky outcrops surrounding Saldanha Bay. There, Dr J. Rogers of the Department of Geological Sciences at the University of Cape Town and a visiting expert from France, Dr J. Giradeaux, showed the participants the evidence of various earlier sea levels through beach deposits from the last inter-glacial period. This tied into the lecture by Dr Woodworth on global warming on sea-level change.

2.7 AFRICAN SEA LEVEL DAY

Wednesday, 25 November was devoted to African sea level, not only with respect to measurements observations and processes important to Africa, but also to give the participants the opportunity to present insights gained during the Workshop. The day started with two presentations, by Dr. Waldron from the University of Cape Town and by Mr R. van Ballegoyen from the Council for Scientific and Industrial Research (CSIR) in South Africa. Dr Waldron showed how appropriately filtered sea-level observations could be used as an index of upwelling along the west coast of South Africa. Such use of sea level as an oceanic climate proxy was of interest to other participants and the possibility of future collaborative research in West Africa was explored. Mr van Ballegoyen is concerned in his work with effective modelling of tidal currents and their effects on off-shore development. Through numerical model animations, he showed some results of his studies from the Saldanha Bay in South Africa and off Mombasa in Kenya.

Professor Brundrit then gave a presentation on the comparative study of sea level around Africa. This presentation was divided into three parts. The first dealt with the need to move towards operational forecasts of sea level rather than just tides alone, by incorporating short term forecasts of meteorological variables into the procedure. This was illustrated in the next part which linked sea-level analysis to extreme events, and their impacts on the coastal environment. Particularly relevant to Africa was the dominant role played by extreme tides in determining especially vulnerable periods where coincidental storms could be particularly damaging. Finally, the extent to which the processes in sea level displayed longshore coherence over entire sections of the African coast and the advantages for regional cooperation in sea-level studies were highlighted.

A number of the Workshop participants from East Africa are involved in the Western Indian Ocean Sea-Level Project being undertaken within the framework of the IOC-Sida-Flanders Marine Science Programme in the IOCINCWIO region. Country Reports in a draft format were available and were introduced by the relevant participant. At the moment, the reports are preliminary but, nevertheless, the discussion was valuable and particularly appreciated by the West African delegates as an example of the fruits of a regional approach to sea level.

It was hoped that the link with the ODINEA Workshop, immediately following this Workshop, could have been made through a presentation by Dr Odido, but unfortunately this was not possible. The importance of regional oceanographic data centres in Africa was, however, taken up by Professor Brundrit, when he reported on the principal recommendations from the Pan-African Conference on Sustainable Integrated Coastal Management held in Maputo, Mozambique in July 1998. This Conference also saw the beginning of the Global Ocean Observing System in Africa, as an Interim Coordinating Committee charged with encouraging the formation of National and Regional GOOS-Africa Committees.

Regional Recommendations

The Workshop divided into regional groups in order to discuss local priorities which would be of assistance in formulating overall recommendations from the Workshop.

WEST AFRICA REGION

Discussion was between the representatives of Nigeria, Ghana, Côte d'Ivoire and Senegal. The representative of Brazil joined this group. The discussion focussed on the following topics:

(i) Equipment needs to be reinforced in the region as a whole.

Nigeria needs computers and relevant software. There are no operational tide gauges in Ghana, two replacements are needed. Côte d'Ivoire needs two tide gauges. Senegal needs one more tide gauge. Brazil has more than twenty operational tide gauges, but needs more training to cope with the data flow. Computers and data loggers are needed throughout the region.

(ii) Coastal Erosion is a major problem that affects the whole region. Consequently, the following are needed:

- a coastal map of the region, highlighting sensitive areas;
- a regional programme based on the availability and use of sea-level data;
- a regional network.

Regional Data Bank

One country in the region should be identified as host for the establishment of the regional sea-level data bank.

Regional Cooperation

Regional cooperation should be encouraged by providing funds to convene regional workshops annually.

Contact should be made with the relevant authorities in the other countries of the region.

Recommendations

Based on the presentations made at this Workshop, the following recommendations were formulated:

There should be a follow-up training workshop:

(i) training should be twice a year, firstly on data analysis and assessments, and secondly on computer software; more advanced material should be included each year;

(ii) each participant should submit an abstract for the next training workshop, based on the experience of the present workshop;

There should be an African sea-level data network:

(i) it should be coordinated by Professor Brundrit;
(ii) South Africa should be the Headquarters;
(iii) it should be equipped with storage facilities;
(iv) publication in form of a Newsletter, such as the Afro-America GLOSS News;
(v) nominate the Steering Committee from each region at the end of the Workshop;
(vi) a letter of invitation to join the Network should be sent to all African countries.

SOUTHERN AFRICAN REGION

Angola. As a start, the authority responsible for tidal observation will be identified in order to make formal contacts and enquiries as to the availability of data (action: SAN Hydrographic Office).

Namibia. Good communications have been established. Current plans include:

(i) The acquisition and installation of two tide gauges by Namibia. South Africa will assist whenever required.

(ii) SAN Hydrographic Office will:

- make available all relevant historical data;
- continue to operate existing gauges as long as required in tandem with new gauges;
- continue to produce predictions for Namibian ports as long as necessary, and perhaps explore the requirements for a joint publication on the joint network.

SAN Hydrographic Office. Future upgrading will include:

- improving the quality of the SRD gauges;
- acquiring new float-actuated digitally-transmitting gauges to operate in tandem;
- planning to add to tidal stations, at least the GLOSS sites: GPS receivers, barometers, anemometers and sea temperature sensors; in doing so the SAN HO will keep Namibia informed;
- re-examining the possibility of a tide gauge on Marion Island. Advice must be sought from the Australian National Tidal Facility;
- expanding the data available on the SANDF Web site;
- developing the in-house capacity for tidal data analysis.

University of Cape Town

(i) Intends to expand the data available on its Web site < http//www.sea.uct.ac.za > to include:
- hourly heights, both observed and calibrated and edited for all Namibian & S.A. ports;
- tidal predictions for the same ports (current year plus 2 years hence);
- raw hourly heights, monthly;
- atmospheric pressure and wind data from the South African Weather Bureau;
- 14-day and 3-day surge predictions.

(ii) UCT continue to be the co-ordinator of tidal data for the region and will ensure the availability of this data to the PSMSL, GLOSS, WOCE, TOGA and any other users by means of a series of hot links.

Mozambique. The desirability of linking Mozambique into the Southern African Region is recognized. Cordial relations exist between INAHINA and the SAN Hydrographic Office which will encourage the increased exchange of data and information between the two organizations.

WESTERN INDIAN OCEAN REGION

Important Priorities:

Equipment:

- New tide gauges and spare parts for some of the non-operational stations, e.g. Aden and Socotra Island in Yemen, Mtwara and Dar-es-Salaam in Tanzania, Inhambane in Mozambique, Agalega in Mauritius.
- Levelling for the Tanzania and Mozambique tide stations.

Regional Network:

- A regional network is in place, which covers all the WIO-Region countries (Mauritius, Mozambique, Kenya, Yemen, Tanzania). At the moment we have a report concerning the status of tidal recordings in each country, as well as in South Africa.

Recommendations:

(i) a follow-up on the NETWORK report recommendations;

(ii) training for the maintenance and installation of tide gauges in some countries;

(iii) funds for maintenance of the tide gauges be sought for both from internal and external sources;

(iv) need to use the available software, e.g. TASK-2000, TOGA to do tidal analysis. This will enable comparisons to be done within the region;

(v) need to have weather stations for measuring sea surface temperature, wind, pressure, etc.

(vi) apply sea-level data in multi disciplinary research studies, e.g. coastal erosion, storm surges, upwelling and fishery studies, just to mention but a few.

3. WORKSHOP ACHIEVEMENTS AND RECOMMENDATIONS

Capacity building:

The Training Workshop, through its presentations, field excursions and hands-on training sessions, was able to enhance the capacity for conducting sea-level activities in Africa. The participants were exposed to fundamental knowledge on the ocean environmental processes responsible for sea-level variability on both the tidal and climatic scales, and to the latest observational equipment and techniques. The hands-on training sessions made full use of the TASK-2000 software for tidal analysis, sea-level analysis and tidal forecasting. With the comprehensive observational data sets available from the GLOSS Station Handbook, most participants were able to construct tide tables for the year 2000 for a tide gauge site in their own country from the historic data. They were also able to appreciate the need for stringent quality control in the operation of their tide gauges. Each participant returned home with disks containing the TASK-2000 software, examples of tidal predictions and observational data sets used in the Training Workshop.

Recommendations:

The Workshop recommended the formation of an African GLOSS Network to coordinate future sea-level activities in Africa. In doing this, the Workshop recognised that GLOSS consisted of a number of elements such as a tide gauge network for sea-level observations, the GPS monitoring of land levels at specific sites, a programme of altimetric coverage of the global ocean, provision of modern methods of data acquisition and exchange, initial and on-going professional training , and of sea-level research in regional as well as global programmes. All these elements should find their place in the African GLOSS Network. In order for the Network to make progress, it was felt that there should be three overlapping regional groups: a West African Group, a Southern African Group and a Western Indian Ocean Group. Group coordinators were elected: E. A. Adekoya from Nigeria for the West African Group, G. B. Brundrit from South Africa for the Southern African Group and M. Odido from Kenya for the Western Indian Ocean Group. Professor Brundrit was elected as the overall Chairman of the African GLOSS Network.

It was noted that there was a need to upgrade the tide gauge network on a regional level. For example, the two sites at Takoradi in Ghana and at Aden in Yemen had long records but were now non-operational. The Regional Groups would be prepared to make recommendations for tide gauge replacements to the IOC Group of Experts in response to requests as opportunities arose. It was also noted that the Workshop had demonstrated the power of information availability and exchange with its use of the WWW, ftp and CD-Roms. The African GLOSS Network would require compatible local computer systems and procedures to be established.

To this end, it was recognised that Regional Oceanographic Data Centres could play a key role in providing access to sea-level data and linking it to regional oceanographic and coastal data of local importance. Such RODCs are operational in the Southern African Region and the Western Indian Ocean Region. In particular, the concept and operating model of ODINEA in the Western Indian Ocean Region should be transferred to the West African Region as a matter of the highest priority.

With the empowerment gained at the Training Workshop, the participants realised that they now had the means to embark on some tidal and sea-level forecasting initiatives. It was recognised that such initiatives would have several on-going benefits. There would be the immediate generation of funds, which in turn would enhance the ability to develop and support further work. There was also the visibility that successful initiatives would bring in improving the chances of future infra-structural support from both private and public sector in each country of the region. The regional cooperation as part of the African GLOSS Network was an important element in deriving full value from these initiatives.

4. CLOSURE

The participants considered the record of discussions and recommendations in a draft report of the Workshop and adopted them in principle. Further editing and refinement would take place with the involvement of the participants, before the submission of the Final Report to the IOC in 1999. Certificates of Attendance at this Training Workshop on Sea-Level Data Analysis were awarded to all participants.

ANNEX I

WORKSHOP PROGRAMME AND TIMETABLE

WEEK 1	MONDAY	TUESDAY	WED. Simon's Town Day	THURSDAY	FRIDAY
0900 - 1030	Formal Welcome. Introduction to Se -level. **Brundrit** **Trotte**	Introduction to Tides **Baker**	Tide gauge types. SA tide gauge network. **Thomson**	GPS, Absolute gravity, Geodetic networks **Baker**	Deep sea pressure recorders. **Woodworth**
	B	R	E	A	K
1100 - 1230	6 x 15 minute introductions by attendees	6 x 15 minute introductions by attendees	Visit to tide gauge site. Data transmission **Thomson**	GLOSS local levelling standards **Baker**	Satellite Altimetry, sea level and tides **Woodworth**
	L	U	N	C	H
1330 - 1500	(HOTS) GLOSS data and Tidal packages **Woodworth**	Sea level and climate change **Woodworth** **Brundrit**	Excursion to penguin colony.	HOTS Tidal analysis examples	HOTS Tidal prediction
	B	R	E	A	K
1515 - 1630	International Programmes **Trotte**	IPCC **Woodworth** **Trotte**	Shopping and Museums.	HOTS Cont'd **Brundrit**	Tide station inter-comparisons **Woodworth**
WEEK 2		West Coast Day	African Sea level Day		
0900 - 1030	Land networks and vertical movements **Baker**	Excursion - Tidal circulation (Cont'd)	Sea level as an index of upwelling. **Waldron** Modelling studies. **van Ballegoyen**	Draft meeting report **Brundrit** **Waldron**	W.I.O. Sea Level Project. **Waldron**
	B	R	E	A	K
1100 - 1230	Levelling exercises **Merry**	between bay and lagoon. **Krug**	Comparative studies around Africa **Brundrit**	Closing ceremony	HOTS wrap-up session **Brundrit**
	L	U	N	C	H
1330 - 1500	HOTS Sea level analysis (Cont'd)	Erosion and extremes. Geological (Cont'd)	**Attendees contributions**	Free Afternoon	
	B	R	E	A	K
1515 - 1630	Links to other observations **Brundrit**	perspective of recent sea level change **Rogers**	**Attendees contributions**		

ANNEX II

LIST OF PARTICIPANTS

I. TRAINEES

Bassirou **Diaw**
Centre de Recherches Océanographiques
de Dakar Thiaroye
B.P. 2241
Dakar
Senegal
Tel: 221 834 80 41
Fax: 221 834 27 92
E-mail: bdiaw@crodt.isra.sn

C. **Souleymane**
Centre de Recherches Océangraphiques
B. P. V18
Abidjan
Côte d'Ivoire
Tel: 225 355014/355880
Fax : 225 351155
E-mail : gog-lme@africaonline.co.ci

Marcus **Tabil**
Survey Dept.
P.O. Box 191
Accra
Ghana
Tel: 233 21 777082/233 028 215980
E-mail: marcusamos@yvccc.africaonline.com.gh

E. A. **Adekoya**
Nigerian Institute for Oceanography and Marine Research
PMB 12729
Victoria Island, Lagos
Nigeria
Tel: 234 1 619517
Fax : 234 1 619517
E-mail: niomr@linkserve.com.ng
(attn EA Adekoya)
E-mail: cmigosi@recoscix.com

Aina T. **Iita**
Ministry of Fisheries and Marine Resources
P.O. Box 912
Swakopmund
Namibia
Tel: 264 64 405744
Fax: 264 64 404385
E-mail: aina@fisheries.gov.na

H. N. **Waldron**
Department of Oceanography
University of Cape Town
Rondebosch 7701
South Africa
Tel: 27 21 650 3284
Fax: 27 21 650 3979
E-mail: waldron@physci.uct.ac.za

Veronica **Dove**
Instituto de Investigacao Pesqueira
P. O. Box 4603
Maputo
Mozambique
Tel: 258 1 49 05 36/49 03 07
Fax : 258 1 49 21 12
E-mail : nica@magumba.uem.mz

Shigalla **Mahongo**
Tanzania Fisheries Research Institute
P. O. Box 9750
Dar-es-Salaam
Tanzania
Tel: 255 51 650045
Fax : 255 51 650043
E-mail : mahongo@hotmail.com

Clive M. **Angwenyi**
Kenya Marine and Fisheries Research Institute
P.O. Box 81651
Mombassa
Kenya
Tel: 254 11 47 5157
Fax : 254 11 47 11 29

Gamal **Bawazir**
Aden Labours Island, House No. 10
P. O. Box 414
Aden
Yemen
Tel: 967 2 23 43 79
Fax : 967 2 25 28 55
E-mail: binsanad@y.net.ye

B. H. **Dunputh**
Meterological Service
St Paul Road
Vacoas
Mauritius
Tel: 230 686 1031
Fax : 230 686 1033
E-mail: meteo@intnet.mu
(attn BH Dunputh)

Agenor **da Silva**
Av. General San Martin 300/201
Leblon
Rio de Janiero, RJ 22441-010
Brazil
Tel 55 21 239 77 17
Fax : 55 21 296 1033
E-mail: prof_agenor@hotmail.com

II. INVITED LECTURERS

P. L. **Woodworth**
Permanent Service for Mean Sea Level
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead
Merseyside L43 7RA
United Kingdom
Tel: 44 151 653 8633
Fax: 44 151 653 6269
E-mail: plw@pol.ac.uk

T. F. **Baker**
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead
Merseyside L43 7RA
United Kingdom
Tel: 44 151 653 8633
Fax: 44 151 653 6269
E-mail: tfb@pol.ac.uk

Janice R. **Trotte**
GOOS Project Office
IOC-UNESCO
1, rue Miollis
75732-Cedex 15
Paris
France
Tel: 33 1 45683978
Fax: 33 1 456 858 12
E-mail: j.trotte@unesco.org

III. LOCAL ORGANIZING COMMITTEE

G. B. **Brundrit**
Department of Oceanography
University of Cape Town
Rondebosch 7701
South Africa
Tel: 27 21 650 3277
Fax: 27 21 650 3979
E-mail: brundrit@physci.uct.ac.za

M. **Thomson**
Superintendent Tidal Information
SAN Hydrographic Office
Private Bag X1
Tokai 7966
South Africa
Tel: 27 21 787 2403
Fax: 27 21 787 2233
E-mail: hydrosan@iafrica.com
(attn Capt M. Thomson)

K. P. **Findlay**
Manager, Centre of Marine Studies
University of Cape Town
Rondebosch 7701
South Africa
Tel: 27 21 650 3283
Fax: 27 21 650 3283
E-mail: cms@physci.uct.ac.za

Marjolaine **Krug**
Department of Oceanography
University of Cape Town.

Charles **Merry**
Department of Geomatics
University of Cape Town.

John **Rogers**
Department of Geological Sciences
University of Cape Town.

Roy van **Ballegoyen**
Council for Scientific and Industrial Research
Stellenbosch
South Africa.

IV. OTHER PARTICIPANTS

Mark Majodina
South African Weather Bureau
and UCT

Greville Nelson
Sea Fisheries Research Institute
and UCT.

Ashley Johnson
Sea Fisheries Research Institute
and UCT

Mike Roberts
Sea Fisheries Research Institute
and UCT

Carl Wainman
Institute for Maritime Technology
and UCT

Ulrich Schultz
Hydrographic Office
South African Navy

Chris van der Vent
Hydrographic Office
South African Navy

Norman Jonas
Hydrographic Office
South African Navy

Antonio Ingles da Silva
UCT (Angola).

ANNEX III

COURSE FACILITIES AND REFERENCE MATERIALS

The Workshop took place in the Blue Micro Laboratory in the Department of Electrical Engineering at the University of Cape Town. The Micro Laboratory contained 40 personal computers linked in a local area network, with common software and information packages pre-loaded. Blackboard, overhead projection and pc-controlled projection facilities were available.

Reference books manuals used in the course included:

1. *The GLOSS Implementation Plan - 1997*. IOC Technical Series No. 50, UNESCO.

2. & 3. *Manual on Sea-Level Measurement and Interpretation*. IOC Manuals and Guides No.14, volume I: *Basic Procedures* (1985) and volume II: *Emerging Technologies* (1994), UNESCO.

4. *Status Report on Existing Ocean Elements and Related Systems*. IOC/INF-1072, GOOS Report no. 32 1997, UNESCO.

5. *Proceedings of the workshop on methods for monitoring sea level: GPS and tide gauge benchmark monitoring and GPS altimeter calibration*. Edited by R Newline, PA van Scoy and P. L. Woodworth. Workshop held at the Jet Propulsion Laboratory, 17-18 March 1997. 202 pp.

6. *Tides, Surges and Mean Sea Level*. D. T. Pugh, John Wiley and Sons, ISBN 0 471 91505 X Compact disks
GLOSS Station Handbook, published on behalf of the IOC by the BODC, July 1996.
WOCE Global Data, version 1.0, BODC and UHSLC, May 1998.
Sea-Level Data from the TOGA SLC and PSMSL, NODC-42
Web sites:
http:/www.pol ac uk/psmsl/sea_level.htm for the GLOSS Station Handbook
http:/www.elsevier.com:80/homepage/sad/mmo/tsp.htm For Tidal Synthesis and Prediction
ftp://bisag.nbi.ac.uk/pub/general/plw/task for the TASK-2000 software
Supplied on disk
TASK2000.zip TASK-2000 software
SA-TIDE.zip South African tidal predictions for 2000