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IOC/JCOMM Training Course for the Global Sea Level Observing System (GLOSS) on Sea Level Observation and Analysis

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Abstract

This report provides a summary of a IOC/GLOSS Workshop on Sea-Level Observation and Analysis. The main objective of the workshop was to train tide gauge operators in the Asia Pacific on sea level hardware and software and aspects of sea level science. The report provides an overview of methods and materials used in the region and provides a set of recommendations for future sea level activities.

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1. INTRODUCTION

The Intergovernmental Oceanographic Commission's (IOC) Global Sea Level Observing System programme (GLOSS) has traditionally emphasized strong training, education and mutual assistance components. Through the TEMA program IOC has encouraged Members States to assist developing countries to actively participate in GLOSS and to apply the expertise gained to national practical concerns. At the 7th GLOSS Group of Experts (Hawaii, 2001), Malaysia (represented by the Department of Survey and Mapping Malaysia (JUPEM)) offered to host a training workshop on sea level observation and data analysis for the countries in the South East Asian region. In this framework of cooperation between JUPEM and IOC, a regional training workshop on Sea Level Observation and Data Analysis was held at Kuala Lumpur, Malaysia from 9-20 February 2004.

The main objective of this workshop was to train and educate tide gauge operators to gain expertise in sea level hardware and software and in some aspects of sea level science. It is hoped that more countries will participate in GLOSS and hence contribute data for global science and local applications.

2. WORKSHOP

The main part of the Workshop was devoted to formal presentations, discussions and hands-on-training in sea-level measurements and analysis. In addition, a field trip was arranged to visit the JUPEM tide gauge station at Tanjung Keling, Melaka. JUPEM also organised trips to the Petronas Twin Tower, Kuala Lumpur Tower and the Putrajaya Federal Administrative Centre to provide the participants with some insights on the economic development in Malaysia.

The agenda for the Workshop can be found in Annex I. The list of participants and lecturers are given in Annex II and III and the list of course reference materials is provided in Annex IV.

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

2.1 OPENING

The Workshop was held in the Nuri 4 Seminar Room of the De Palma Hotel. Dr Thorkild Aarup, the Technical Secretary of GLOSS, provided welcoming remarks on behalf of Dr Patricio Bernal, Executive Secretary of IOC. He conveyed Dr Bernal's thanks to the JUNEP and to the JUNEP staff for all their hard work and excellent planning efforts. He also paid tribute to the local organising committee (chaired by Dr Abdul Kadir bin Taib) and acknowledged the financial support to the workshop from the French IOC Committee, the European Space Agency, the Natural Environment Research Council of the United Kingdom and the Jet Propulsion Laboratory /National Air and Space Administration (USA). The workshop was then officially opened by Mr. Hamid Ali, the Director General of Survey and Mapping of JUPEM who whished the participants a successful course.

2.2 LECTURES

2.2.1 IOC, GLOSS and GOOS - Dr Thorkild Aarup

Dr Thorkild Aarup provided a brief overview of the IOC. The IOC of UNESCO provides member states of the United Nations (UN) with an essential mechanism for global scientific cooperation in the study of the ocean. The IOC assists governments in addressing ocean and coastal problems through the sharing of knowledge, information and technology. The needs for sea level data were highlighted and some information on sea level rise was presented. The need for a long-term commitment to high quality sea level observations was emphasized together with the provision of high frequency and real-time data. The GLOSS programme aims to establish high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level research. The GOOS programme is a sustained, coordinated international system for gathering data about the oceans and seas of the earth. GOOS will include the processing of such data into beneficial products and services, and it will include the research and development upon which such products and services depend for their improvement.

2.2.2 Introduction to Sea Level and Ocean Tides – Dr Simon Williams

This lecture provided a brief introduction to geodesy, the geoid and sea level. The different geodetic surfaces used to describe sea level were presented such as the spheroid, ellipsoid and geoid. Due to the density of the waters, the dynamic nature of the oceans and variations in atmospheric pressure, the sea surface is permanently displaced from the geoid, usually between several centimetres to a meter. The height of the ocean surface above the geoid represents the sea surface topography. The lecture continued with a simple explanation of tides and the various dominant geophysical forcing functions. Various types and patterns of tides were presented. The various causes of tides were explained – centripetal force and gravitational force and its magnitude of influences on the tides. The equilibrium tide and the tidal constituents were explained further and the geometry of the Earth-Sun System was presented graphically to relate the various tidal constituents.

2.2.3 Climate Change 2001: The Scientific Basis – Dr John Church

A report of the Working Group I of the Intergovernmental Panel on Climate Change (IPCC) on climate change was presented in this lecture. Global observations now show a collective picture of a warming world and the global average surface temperature has increased over the 20th century by about 0.6º C. Four different annual temperature trends were analysed over four different time periods. Reconstructions of climate data for the last 1000 years indicated that the 20th century warming was unusual and is unlikely to be entirely natural in origin. The report presented also pointed out that the concentration of atmospheric greenhouse gases have continued to increase as a result of human activities. The report warned that human influence will continue to change the atmospheric composition throughout the 21st century. Some of the contributions to sea level change were also outlined, namely, the ocean thermal expansion, melting glaciers, Antarctic and Greenland ice sheets and terrestrial storage. Long-term projections also indicated continued glacier melting, uncertainty about the stability of the West Antarctic ice sheets, continued thermal expansion for centuries and Greenland melting. The final points on the report mentioned that the earth is experiencing a major change in the climate system; anthropogenic climate change will persist for many centuries; stabilization of concentration will require reductions in emissions and further action is required to address remaining gaps in information and understanding.

2.2.4 Tidal Analysis and Mean Sea level – Dr Simon Williams

The lecture began with a description of the non-harmonic methods used in the tidal analysis. These methods, although simple, basically contain insufficient information for a full tidal description and prediction scheme and were too optimistic for scientific work. The lecture continued with the method of harmonic analysis used for the processing of tidal observation. This method assumes that tidal variations can be represented by a finite number of harmonic terms. These harmonic terms have the basic periods and frequencies of astronomical motion that can be grouped into long period, diurnal, semi-diurnal and tri-diurnal constituents. Shallow water terms due to the interaction of the tidal wave with a shoaling seabed were also briefly mentioned. The criteria and rules to select the constituents for analysis were outlined. The final part of the lecture concerned Mean Sea Level (MSL). MSL was defined and its determination through arithmetic means or low-pass filters was presented. One of the major limitations on the study of long-term sea level change measurements is the stability of the Tide Gauge Benchmark (TGBM). Finally the two causes of sea level changes: epirogenic and eustatic were mentioned.

2.2.5 Sea Level Rise – Dr John Church

Dr John Church presented the chapter on Changes in Sea Level from the IPCC Third Assessment Report. This chapter was co-authored by Jonathan Gregory, Phillipe Huybrechts, Michael Kuhn, Kurt Lambeck, Mai Tran Nhuan, Da He Qin, and Phillip Woodworth. In the presentation, historical sea-level changes were described and some of the recent estimates of sea level rise from tide gauges around the world were shown. These ranged from 1.0 mm/yr to 2.4 mm/yr. The relationship between global mean sea level and the sea surface temperature was also described. The amount of contributions by various sources and projections for 1990-2100 were also described. The findings of the authors were that: the sea level had risen by over 120 m since the last glacial maximum (LGM); sea level rise during the 20th Century had been 1 – 2 mm/yr; the rate of increase had been greater than the past millennia and a few long records indicate an acceleration; no indication of acceleration in observation or models during the 20th century; sea level was projected not to rise uniformly, an increase in the frequency of surges of a given level and continued sea level rise long after greenhouse gas concentration are stabilised.

2.2.6 Space Geodesy for Vertical Land Movements – Dr Simon Williams

An overview of the geodetic methods for the purpose of geodesy, surveying and sea level measurements was presented, namely Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), the Global Positioning System (GPS), Absolute Gravity, Interferometric Synthetic Aperture Radar (INSAR) and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). These techniques were described extensively in the context of determination of the time series of real sea level and its spatial variation. Three examples were given of the application of the Global Navigation Satellite System (GNSS) in sea level measurement, monitoring and analysis. An overview of the use of GPS at tide gauges for sea level and vertical land movements monitoring was provided. The difference between relative MSL and absolute MSL was explained. Several projects were mentioned including the Sea Level Fluctuation (SELF I) Project and the EUROGAUGE Project. Some of the recommendations by the International GPS Service (IGS) / Permanent Service for Mean Sea Level (PSMSL) on (i) the location of continuous GPS stations; (ii) periodical measurement of the vertical tie between CGPS station, the tide gauge sensor and TGBM were given. The recommendations by the European Sea Level Observing System (EOSS) on the dual CGPS concept were also presented. The CGPS data processing was also described as well as time series analysis. The CGPS at

British Tide Gauges was mentioned as an example for the sea level and vertical land movement monitoring.

2.2.7 International Oceanographic and Climate Programme – Dr John Church

The four major research programmes in the Earth System Science Partnership (ESSP) were described in this lecture. These are the World Climate Research Programme(WCRP), the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme on Global Environmental Change (IHDP) and DIVERSITAS - an integrated programme of biodiversity science. ESSP Joint Projects focus on aspects of global change that are critical to human well being. At present, these initiatives cover four areas: carbon/energy systems, food, water, and human health. The lecture began with an explanation of the WCRP with its objective of climate predictability and to study the effect of human activities on climate. WCRP works closely with the ICSU/WMO/IOC/UNEP Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS). The Ocean Observation Panel for Climate (OOPC) overseeing the implementation of an ocean observation system for GCOS (or, equivalently, the climate component for GOOS) and works closely with the GCOS Atmospheric Observation Panel for Climate (AOPC). WCRP collaborates with IGBP and IHDP in the development of the System for Analysis, Research and Training (START). Some of the projects and components carried out by WCRP are the now completed World Ocean Circulation Experiment (WOCE), Climate Variability and Predictability (CLIVAR). The Global Ocean Data Assimilation Experiment (GODAE) is organized by the OOPC. IGBP is a scientific research programme built around six Projects that focus on the major Earth System compartments and the interfaces between them, and two Framework Activities. DIVERSITAS is an international global environmental change research programme to promote integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge and to provide the scientific basis for an understanding of biodiversity loss, and to draw out the implications for the policies for conservation and sustainable use of biodiversity.

2.2.8 Absolute Gravity: UK and Europe Experience – Dr Simon Williams

This lecture focused on the geodetic technique of Absolute Gravity for measuring land movements. First a definition of absolute gravity and a brief description of the methods used and reasons for measuring absolute were given. The design and concept of the FG5 absolute gravimeter was explained together with the methods of data collection and processing. The lecture continued with an outline of the corrections needed for absolute gravity observations namely the earth tide correction, local barometric pressure correction, polar motion correction, ocean loading correction, comparator response correction, speed of light correction, gradient correction and the reference height correction. Some of the applications of absolute gravity in geophysical research, environmental monitoring, exploration and resources management and precision measurement and calibrations were described. The experiences of using Absolute Gravity in the UK and Europe were used to explain its use in global sea level studies for global warming.

2.2.9 Oceanography of the Equatorial, Pacific and Indian Ocean – Dr John Church

The lecture commenced with a description of the El Niño Southern Oscillation (ENSO) phenomena, its fundamentals and the teleconnections during the northern winter and summer seasons. Some of the events and effects of ENSO on agriculture productions in Australia and Indonesia were quoted. The Asian-Australia monsoon system was also affected, particularly the Northwest cloud band, which brought rain to southern Australia. The rate of warming in the

Indian Ocean was rapid during the late 20th century. ENSO's effect on Sea Surface Temperature and sea level was explained further.

2.2.10 Introduction to TASK and Quality Control – Dr Simon Williams

The Tidal Analysis Software Kit 2000 (TASK-2000) package is an updated version of the previously distributed TASK software. The TASK-2000 package is a set of PC-based DOS programs for tidal analysis derived primarily from the TIRA tidal analysis programs (Murray, M.T. 1964. A General Method for the Analysis of Hourly Heights of the Tide. International Hydrographic Review, 41(2), 91-101) used at the POL for many years. They have been supplemented by DOS-compatible plotting software supplied by the POL Applications Group. The Proudman Oceanographic Laboratory (POL) and the Permanent Service for Mean Sea Level (PSMSL) provided the programmes files for use by educational and research establishments in the course of sea level research. The main programmes are the tidal analysis programme (TIRA) and the tidal predictions programme (MARIE). They are used for data checking, filtering, analysis and prediction. Control files are used to provide input and output parameters. This lecture introduced this package and described the procedures for its use.

2.2.11 The Regional Distribution of Sea Level Rise, 1950 – 2000 – Dr John Church

The regional distribution of sea-level rise during the period of 1950-2000 was presented. Historical estimates of global average sea-level rise, according to the IPCC report, have been in the range of 1.0 to 2.0 mm/yr. The larger value was argued by Cabanes to be unrealistic and the result of the inhomogeneous distribution of tide gauges (Cabanes, C., A. Cazenave, C. Le Provost (2001): Sea Level Rise During Past 40 Years Determined from Satellite and in Situ Observations, Science, 294, 840-842). Four main objectives of the study were outlined, namely: (i) To narrow the current range of sea-level rise estimates (ii) To identify patterns of regional sea-level rise (iii) To determine variation in the rate of sea-level rise and (iv) To understand the individual records analytically. The approach taken through the use of satellite altimetry data, expanding of the historical tide gauge data, determining the amplitudes and patterns and taking into account information related to spatial correlations was explored. The results of the analysis were a global rate of mean sea level rise of 1.8 mm/yr.

2.2.12 Introduction to Satellite Altimetry – Prof. C.K. Shum

Through this lecture the participants were introduced to the basic principles of satellite altimetry. Satellite altimetry was formulated in 1969 and was initially designed to measure the ocean and was seen to work effectively in measurements of land and sea ice, land topography, lake levels etc. The coverage for the measurement with respect to different types of satellites was also covered in the lecture. The second part of the lecture covered the principle of satellite altimetry including design and temporal-spatial sampling. Illustrations on the contributing factors to the sea level monitoring were also shown. Emphasis was also given to ocean circulation. The mode of transmission of the satellite signals was elaborated. The geometry of the radar altimeter and the measurement concept was explained and implied that the clock must be accurate to less than 1 second in order to achieve an accurate altitude of less than 1 cm. The participants were also briefed on the different aspects of orbit determination such as dynamic, reduced dynamic and kinematic. Dominant perturbations that affect near-earth orbiting satellites such as gravitational and non-gravitational factors and also the inertial and terrestrial reference frame were discussed during the lecture.

2.2.13 Satellite Altimetry for Sea Level Monitoring – Prof. C.K. Shum

This lecture concerned the problem of solving measurement, prediction and understanding the causes and consequences of sea level rise as well as using the satellite altimetry techniques as a potential tool to measure accurately the global sea level rise. The lecturer also pointed out that in using satellite altimetry for the measurement of global sea level change, factors such as instrument corrections, atmospheric refraction corrections, sea-state bias correction and external geophysical adjustments need to be carried out so as to achieve better results. In addition, internal calibration corrections in the satellites and tide gauge calibrations were also performed.

2.2.14 Geoid and Vertical Datum – Dr Kamaluddin Omar

The lecture focused on the classification of various reference surfaces towards achieving the geoid and a global vertical datum. The nature, characteristics and types of geoid were also described to the participants. The vertical datum, especially for Malaysia was discussed. The Malaysian experience on GPS levelling was highlighted with calculation procedures to enable the best geoid fitting throughout the country. The relative accuracy with respect to the geoid was also illustrated. The unification of the vertical datum was discussed to overcome the problem of vertical control, due to the various datum that existed within the country. It was concluded that the problem can be solved by using the global precise geoid and high precision GPS measurement.

2.2.15 GPS Buoy for Altimeter Calibration and Coastal Circulation – Prof. C.K. Shum

The lecture focused on the GPS buoy system and designs. The functions of the GPS buoy were discussed and the techniques to measure the local geoid height. Absolute calibration of the altimeter was also taught, by deploying the GPS buoy with a tide gauge. This helps to convert the tide gauge levels to the geocentric reference frame and the altimeter bias was estimated by least squares techniques. The nature of the tides as well as the forces acting on to the tides were also explained. The lecturer also spoke on the accuracy assessment of ocean tide models in the coastal regions. The assessment of tide error using model comparisons were also highlighted. The participants were also briefed on the ocean tide solution techniques such as harmonic analysis, orthotide analysis and also a combination of both. The roles of tides in glacier dynamics and ice sheet mass balance were also elaborated.

2.2.16 Satellite Altimetry for Ocean Tide Modelling – Prof. C.K. Shum

Through this lecture, the assessment of tide error was known to be carried out using model comparisons. Altimeter sampling was also carried out because radar altimeters that fly in a ‘repeat’ ground-track do not repeat along the same track. The participants were also briefed on the iterative scheme to estimate the sea surface gradient and mean sea surface. The calculation of the sea level variations were discussed. Subsequently, the calibration and validation of satellite altimeters were then mentioned and a comparison of sea level change between tide gauge and altimeter was also illustrated. Finally, the participants were also briefed about the future aspects of satellite altimetry techniques such as wide-swath altimeter, Delay-Doppler altimeter and also the Ka-Band altimeter.

2.2.17 Precise Levelling for Tide Gauge Benchmark Connection – Dr Shahrum Ses

The lecture consisted of the conceptual understanding of the application of precise levelling related to engineering or constructional application as well as the determination of vertical datum of reference. The participants were briefed on the concept of heights and the realisation of the vertical datum with reference to the geoid or mean sea level. The main errors in levelling which includes instrumental and environmental errors were also highlighted of which the gravity and magnetic field of the earth were taken into consideration. Subsequently, the identification of the Benchmarks, instrumentation and field procedures were described. The lecture also focused on data capture and transfer, application of corrections and the analysis of the quality of the field observation.

2.3 HANDS-ON-TRAINING SESSIONS (HOTS)

There were three hands-on training sessions conducted throughout the workshop. One was on the practical usage of the TASK-2000 software, another one on GPS field observation and a final one on precise levelling survey. The participants were divided into several groups to allow each participant to personally carry out the processing of sample tidal data and handling of the GPS and precise levelling equipment. Each participant was provided with a computer notebook to allow the individual to practice on the software.

2.4 COUNTRY REPORTS PRESENTATION

One afternoon session was allocated for the participants to present the status of tidal observation and analysis in their respective countries. All of the presentations were given in English and a question and answer session followed each presentation to allow the participants to share among themselves their experiences and knowledge in tides and sea level observation.

Pakistan – The participant from Pakistan is an officer with the National Institute of Oceanography. He gave a presentation on Sea Level Monitoring in Pakistan as a Component of Integrated Coastal Zone Management. Pakistan has approximately 990 km of coastline. The coastal zone is divided into two distinct regions, namely, the Sindh coast (Indus deltaic region) and the Baluchistan Coast. There are only two tide gauges, one in Karachi (Sindh) and one in Gwadar (Baluchistan). The tidal observations at Karachi have been in operation for a long time basically for the purpose of smooth port operation. Trend analysis shows that the sea level is rising along the Pakistan Coast at a rate of 1.1 mm/year. The tide station at Gwadar is non-operational. Existing gauges in the country are non operational. Lack of spare parts and adequate funds to run the stations have led to this station being non-operational. Stations have no multi-parameter gauge, nor are they equipped with additional sensors for measuring meteorological parameters. Tide gauges were not equipped with GPS in Pakistan. The GPS method of monitoring vertical land movements at the tide gauge site is a relatively new technique. Since gauges are relatively old, due to the lack of operational funds, they are yet to adopt this technique. The above assessments demonstrate that much work remains to be done. Upgrade/replacement of existing tide gauges and establishment of additional stations are very much required in Pakistan. At present both GLOSS designated stations along the Pakistan coast are not fully operational and do not collect data properly.

Vietnam – The participant from Vietnam is an officer with the Marine Hydrometeorological Center, Vietnam. He gave a presentation on the status of sea level measurement in Vietnam. Vietnam has a dense river system and long coastline exceeding 3200 km. Sea level measurement

and monitoring are necessary for the forecasting and warning of natural calamities. There are 6 marine hydrometeorological observing systems along the coast and on islands that record sea levels every hour. These stations have been in operation for a long time. There are also 4 automatic oceanographic buoys that have been deployed since 1995 for typhoon forecasting and warning. The tide gauge recorders were of CYM type made by Russia, Stevens type made by USA, OT-600 made by France and WRL made by Norway. Hourly sea level data recorded by the tide gauges are checked, processed and analysed using ORKAN and TIDE software.

Thailand – The participant from Thailand is an officer with the Hydrographic Department of the Royal Thai Navy. He gave a presentation on the Tidal Work in Thailand. Thailand has a coastline of 2800 km covering the Gulf of Thailand and Andaman Sea. There are 27 tide gauges that are operated by a number of agencies. The Tides and Tidal Phenomena Project was implemented under ASEAN/Australian Cooperative Program on Marine Sciences. Today, the Hydrographic Department, using 112 constituents for tidal prediction, use the software provided by the National Tidal Facility at the Flinders University, Australia.

Singapore – The participant from Singapore is a lecturer with the Maritime Research centre, Singapore. He gave a presentation on sea level observations in Singapore. Presently, the activities on the sea level observation are carried out by the Hydrographic Department of Maritime Port Authority (MPA) of Singapore, which is responsible for the monitoring, processing and publishing of the tidal level data. There is a total of 12 tidal stations maintained by MPA, of which, the tidal data of 9 stations are published annually in the Singapore Tide Table for maritime usage.

United Arab Emirates – The participant from United Arab Emirates (UAE) is an officer with the Planning and Survey Department, Dubai Municipality, UAE. He gave a presentation on sea level observations in the Emirate of Dubai, UAE. Dubai is located on the south eastern coast of the Arabian Gulf and has a coastline of roughly 67 km. Sea level measurements in the ports are performed by local port authorities and analysed by different companies. The data from these tide gauges are used only as an aid to navigation and sometimes for hydrographic survey of the ports. Generally, hydrographers are using their own tide gauge for bathymetric surveys. No continuous record of tide data is available from Port Rashid station for analysis and the vertical datum reference is not fully traceable. Dubai Municipality decided to remedy the lack of data and work out the relationship between the MSL and Chart Datum by setting up permanent tide monitoring stations and a central data collection and analysis centre. The proposed water level stations uses a high accuracy pressure sensor and the data is recorded digitally at site and also sent to a base station in real time using GSM telephone network. The goal is to monitor the water level with an accuracy of better than one centimetre. Provisions are made within the data processing system to convert the measured water levels to local tidal datum with reference to the Dubai Municipality Datum (DMD). The main objective of the project will be to determine the accurate Chart Datum and Mean Sea Level and connect the vertical datum to the land control points and update the complete network in Dubai. A proposal is also being considered to provide the tidal data on the web page server, which could easily be accessed either internally over an intranet or external via the Internet.

Indonesia – The participant from Indonesia is an officer with the National Coordinating for Surveying and Mapping Agency. He gave a presentation on permanent sea level monitoring in Indonesia. Indonesia is an archipelagic country consisting of nearly 17,000 islands with a total coastline length exceeding 81,000 km. There are a total of 54 tide stations in the National Tide Gauge Network. Two types of sea level recorders are used: 29 stations use the analogue graphical chart of Kempton OTT v. R20 / Steven Leopoid and Fisher (will be replaced with new

Kempton chart recording type R20) and 25 stations use the digital on-line tide gauges with instrument Scanmatic v. SM5075 (will be replaced with new Thalimedes digital recording). Data processing is carried out using the modified windows-based TOGA software. Published data of 5 stations in tabular and graphical format has been produced. There are 8 stations committed as part of the GLOSS network.

India – The participant from India is an officer with the Geodetic Research Branch, Survey of India (SOI). He gave a presentation on the core activities carried out in relation to oceanography. SOI has sent monthly and annual MSL data to the PSMSL for long-term sea level change information. SOI also publish Indian Tide Table comprising 76 Indian and selected foreign ports and HUCLI River Tide Table. It also provides tidal prediction along the sea coast of India on demand. SOI keeps the historical data in computerised form. It carried out a study on precise inter-island drifts impact of global greenhouse effect on sea level rise and the determination of sea level bench marks position to decouple the vertical crustal movements from sea-level variations.

Malaysia – The participant from Malaysia is an officer with the Geodesy Section of the Department of Survey and Mapping Malaysia (JUPEM). He gave a presentation on tidal observation and tidal characteristics in Malaysia. He described the JUPEM tide observation project that stared 23 years ago. The aim of the tide gauge network in Malaysia is to study the tide level and characteristics around Malaysia with the intention of establishing accurate height datum for the country. There are 21 strategically located tidal stations throughout the country (12 in Peninsular Malaysia, 9 in East Malaysia). All the stations use the digital DFT-1 Kwowa Shoka Float-type tide gauges. Tidal analysis is carried out on data sampled with a frequency of 50 seconds. Sixty-eight Harmonic Constants are computed from yearly observation. Study has shown that the prediction is accurate to ± 10 min. in time and ± 20 cm in height. There are three types of tides in Malaysia, namely, the semi-diurnal, mixed type (semi-diurnal dominant) and mixed typed (diurnal dominant). There is now enough data to compute for the 18.61 years of MSL. The published data available are the sea level hourly height at every station, time and Height of '*High Water*' and '*Low Water*', daily, monthly and yearly mean sea level values, harmonic constants, Tide Prediction Table (annual publication) and Tidal Record (annual publication).

2.5 FIELD VISIT

The participants were taken to a tide gauge station in Tajung Keling, Melaka, located about 200 km from the workshop venue. The tide gauge set up was explained and demonstrated to the participants.

3. RECOMMENDATIONS AND CONCLUSIONS

The Workshop was concluded successfully with participants from various countries complimenting the organizers, particularly JUPEM and IOC, for their excellent organization and expert materials. The participants stated that they would make use of the workshop information to further enhance the activities and functions of their work in their own countries. The Workshop benefited from the training materials provided by JUPEM, and from the involvement of JUPEM and the University Technology Malaysia (UTM) in the demonstration of GPS, gravimeter and levelling equipment.

The participants were exposed to the work of the IOC and GLOSS, and many expressed willingness to share their knowledge and tidal data with the larger community, so as to bring about a greater benefit to the global society. The participants also pledged to work with one another to complement any regional project cooperation. It is the hope that collaboration on a regional scale can be set up to allow for greater participation in research and analysis of regional tidal and sea level data.

The country reports highlighted national needs and indicated some areas for potential regional collaboration:

1) Digitisation of historic sea level records;
2) Determination of optimal distribution of tide gauges (perhaps through a regional/national modelling exercise);
3) Upgrade/renewal of national tide gauge networks;
4) Linkage of GPS-receivers with selected tide gauges;
5) Training and information about tide gauge technology.

There was general agreement between the participants that sea level data from individual countries could be shared through some kind of reciprocal arrangement and on a voluntary basis. However, it was also emphasized, that for some of the countries, there are issues of national security and cost recovery that currently hinders delivery of sea level observations, particularly in fast mode to the international sea level data centers.

Malaysia expressed interest in hosting a regional sea level activity web site and IOC/GLOSS will explore this offer and develop a proposal to be discussed further with JUPEM.

Indonesia offered to host a future training course and IOC/GLOSS will explore this offer further.

4. CLOSURE

The workshop was officially closed by Dr Abdul Kadir Taib, the Director of Survey (Mapping Division) of JUPEM. He also thanked the organizer and the IOC for a job well done and thanked the participants for their kind attention and interest in this workshop. Finally he presented certificates to all participants.

ANNEX I

COURSE SCHEDULE

Date/Day	Time	Program/Activities	
08.02.2004 Sunday	1400	Arrival of Participants and Instructors. Check-in at Hotel	JUPEM
09.02.2004 Monday	0830 – 0900	Registration	JUPEM
	0900 – 1030	Official Opening of Training Course by the Director General of JUPEM	
	1030 - 1100	General Brief of Course	Dr Thorkild Aarup
	1100 - 1230	Ice-breaking Session Introduction by attendees from participating countries and detailed statements of individual requirements.	
	1400 - 1530	Introduction to Sea Level and Ocean Tides	Dr Simon Williams
	1600 - 1700	Climate Change 2001: The Scientific Basis	Dr J. A. Church
10.02.2003 Tuesday	0900 – 1000	Tidal Analysis and Mean Sea Level	Dr Simon Williams
	1030 – 1130	Sea Level Rise	Dr J. A. Church
	1130 – 1230	Space Geodesy for Vertical Land Movements	Dr Simon Williams
	1400 – 1530	International Oceanographic and Climate Programme	Dr J. A. Church
	1600 – 1700	Absolute Gravity: UK and Europe Experience	Dr Simon Williams

11.02.2004 Wednesday	0900 – 1000	Oceanography of the Equatorial, Pacific and Indian Oceans	Dr J. A. Church
	1030 – 1130	Introduction to TASK and Quality Control	Dr Simon Williams
	1130 – 1230	The Regional Distribution of Sea Level Rise – 1950 -2000	Dr J. A. Church
	1400 - 1700	HOTS Day	Dr Simon Williams / JUPEM
12.02.2004 Thursday	0900 - 1700	HOTS Day continue	Dr Simon Williams / JUPEM
13.02.2004 Friday	0800 - 1700	Visit to Tide Gauge in Malacca	JUPEM
14.02.2004 Saturday		Visit to Putrajaya and KLCC	JUPEM
15.02.2004 Sunday		Free day	
16.02.2004 Monday	0900 – 1000	Introduction to Satellite Altimetry	Prof. C.K. Shum
	1030 – 1230	Satellite Altimetry for Sea Level Monitoring	Prof. C.K. Shum
	1400 - 1500	Country Reports Presentation	JUPEM
	1530 - 1700	Geoid and Global Vertical Datum	Assoc. Prof. Kamaluddin Omar
17.02.2004 Tuesday	0900 – 1000	GPS Buoy for Altimeter Calibration and Coastal Circulation	Prof. C.K. Shum
	1030 – 1230	Satellite Altimetry for Ocean Tide Modeling	Prof. C.K. Shum
	1400 - 1700	Demonstration of GPS Observation	Assoc. Prof. Kamaluddin Omar / JUPEM
18.02.2004 Wednesday	0900 – 1230	Levelling, Tide Gauge and Benchmark	Dr Sahrum Ses
	1400 - 1700	Levelling HOTS Day	Dr Sahrum Ses / JUPEM

19.02.2004 Thursday	0900 - 1230	Precise Levelling For Tide Gauge Benchmark Connection	Dr Sahrum Ses
	1400 - 1700	Visit to JUPEM	JUPEM
20.02.2004 Friday	0900 – 1000	Wind-up review	JUPEM
	1030 – 1230	General debrief of course	Prof. C.K. Shum JUPEM
	1400 - 1700	Draft workshop report for IOC	JUPEM
21.02.2004 Saturday		Departure of Participants and Instructors	JUPEM

ANNEX II

LIST OF PARTICIPANTS

1. Mr Mehran Samadollah GHASSEMI
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ANNEX III

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ANNEX IV

COURSE MATERIALS

Hardcopy

1. Sea Level Rise – History and Consequences
   Bruce C. Douglas, Michael S. Kearney, Stephen P. Leatherman
   International Geophysics Series. Volume 75

2. Manual on Sea-Level Measurement and Interpretation
   Volume III – Reappraisals and Recommendations as of Year 2000
   Intergovernmental Oceanographic Commission, UNESCO 2002

3. A Review of Sea-Level Research from Tide gauges during the World Ocean Circulation Experiment
   P.L Woodworth, C. Le Provost, L.J. Rickards, G.T. Mitchum & M. Merrifiled
   Oceanography and Marine Biology: An Annual Review 2002

4. Sea Level Change and Coastal Processes Implications for Europe – Research Results and Recommendations
   European Commission Community Research
   Energy, Environment and Sustainable Development

5. Global Sea Level Observing System (GLOSS) Implementation Plan - 1997
   Intergovernmental Oceanographic Commission, technical series, UNESCO

6. Satellite Altimetry
   Dudley B. Chelton, John C. Ries, Bruce J. Haines, Lee-Leung Fu and Philip S. Callahan
   Satellite Altimetry and Earth Science, Chapter 1

7. Large Scale Ocean Circulation
   Lee-Leung Fu and Dudley B. Chelton
   Satellite Altimetry and Earth Science, Chapter 2

8. A One Year Comparison of Radar and Bubbler Tide Gauges at Liverpool
   Philip L. Woodworth and David E. Smith
   The International Hydrographic Reciew Vol.4 No.3 Dec 2003

9. A report on the status of the GLOSS programme and a proposal for taking the programme forward
   Philip Woodworth and Thorkild Aarup
   IOC/INF-1190. Intergovernmental Oceanographic Commission, UNESCO

10. Manual of POL/PSMSL Tidal Analysis Software Kit 2000 (TASK-2000)
    C. Bell, J.M. Vassie and P.L. Woodworth
    Proudman Oceanographic Laboratory

CDs

1. Satellite Altimetry For Geodesy, Geophysics and Oceanographic

2. Sea Level Rise

3. Papers by Prof. C.K. Shum

4. Lecture Presentations of Dr Simon Williams, Dr John Church, Dr Thorkild Aarup, Prof. C.K. Shum, Assoc. Prof. Kamaludin Omar and Dr Shahrum Ses

5. TASK Software

6. Photographs Sessions at the Workshop

Photographs

ANNEX V

LIST OF ACRONYMS

AOPC	Atmospheric Observation Panel for Climate
ASEAN	Australian Cooperative Program on Marine Sciences
CGPS	Continuous GPS
CLIVAR	Climate Variability and Predictability
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
EOSS	European Sea Level Observing System
ENSO	El Nino Southern Oscillation
ESSP	Earth System Science Partnership
GCOS	Global Climate Observing System
GLOSS	Global Sea Level Observing System
GNSS	Global Navigation Satellite System
GOOS	Global Ocean Observing System
GPS	Global Positioning System
HOTS	Hands On Training Sessions
ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IGS	International GPS Service
IHDP	International Human Dimensions Programme on Global Environmental Change
INSAR	Interferometric Synthetic Aperture Radar
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
JUPEM	Department of Survey and Mapping Malaysia
LGM	Last Glacial Maximum
MARIE	Tidal prediction programme
MSL	Mean Sea Level
OOPC	Ocean Observation Panel for Climate
POL	Proudman Oceanographic Laboratory
PSMSL	Permanent Service for Mean Sea Level
SLR	Satellite Laser Ranging
START	System for Analysis, Research and Training
TASK	Tidal Analysis Software Kit
TEMA	Training, Education and Mutual Assistance
TGBM	Tide Gauge Benchmark
TIRA	Tidal analysis programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Science and Cultural Organization
UTM	University Technology Malaysia
VLBI	Very Long Baseline Interferometry
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment

IOC Training Course Reports

No.	Title	Language
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, 16 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

No.	Title	Language
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 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

No.	Title	Language
40.	IOC-DANIDA Training Course on the Taxonomy and Biology of Harmful Marine Microalgæ; University of Copenhagen, Denmark, 31 July-11 August 1995; IOC-SAREC-DANIDA Training Course on the Taxonomy and Biology of Harmful Marine Microalgæ; University of Mauritius, Republic of Mauritius, 5-14 February 1996; and Annual Report 1995, IOC Science and Communication Centre on Harmful Algæ, DANIDA, University of Copenhagen, Danish Fisheries Research Institute, Danish National Environmental Research Institute	English
41.	IOC-Germany Advanced Training Course on Bathymetric Charting in the Western Indian Ocean METEOR, 15-29 December 1995	English
42.	COI-SHOA-CICESE Curso Sobre Modelación Numérica de Tsunamis Valparaiso, Chile, 11 de Marzo - 11 de Mayo de 1996	Spanish
43.	Seminario/Taller de la COI/GLOSS-SHN sobre Observación y Análisis del Nivel del Mar para países de habla hispano-portuguesa de Latinoamérica Servicio de Hidrografía Naval (SHN), Buenos Aires, Argentina, 19-27 de noviembre de 1996	Spanish
44.	IOC-INCO-ROPME Training Course on Oceanographic Data and Information Management, Tehran, Iran, 19-30 October 1997	English
44.	IOC-ICSU-IAEA-EU Training Course on Marine Geological and Geophysical Data Management for the Countries of the Black and Caspian Seas Regions, Gelendzhik, Russian Federation, 8-19 September 1997	English
45.	IOC-ICSU-IAEA-EU Training Course on Marine Geological and Geophysical Data Management for the Countries of the Black and Caspian Seas Regions Gelendzhik, Russian Federation, 8-19 September 1997	English
46.	Training Course on Management of Marine Data and Information for the IOCINCWIO Region Mombasa, Kenya, 1-11 December 1997	English
47.	IOC/WESTPAC-SIDA-SAREC-SEAPOL Training Workshop on Operational Data and Information System for the Gulf of Thailand Bangkok, Thailand, 18-21 November 1997	English
48.	SZN-IOC Advanced Phytoplankton Course on Taxonomy and Systematics Vico Equense, Naples, Italy, 10-30 May 1998	English
49.	First IOC/WESTPAC Training Course on Monitoring of PSP Plankton and Shellfish Toxicity, Japan, July 1995 Second IOC/WESTPAC Training Course on Species Identification of Harmful Microalgæ, Japan, February 1997 Third IOC/WESTPAC Training Course on Species Identification of Harmful Microalgæ, Japan, August 1997	English
50.	IOC/IODE-NIO Training Course on Oceanographic Data and Information Management Goa, India, 17–27 October 1998	English
51.	IOC/GLOSS-GOOS Training Workshop on Sea-Level Data Analysis South Africa, 16–27 November 1998	English
52.	IOC-UNEP Germany Training Course on Qualitative and Quantitative Determination of Algal Toxins, Jena, Germany, 2-12 March 1999	English
53.	*Cancelled*	
54.	IOC/GLOSS-GOOS Training Workshop on Sea-Level Measurements, Tidal Analysis, GPS and Gravity Measurements, Satellite Altimetry and Numerical Modelling Sao Paulo, Brazil, 30 August-25 September 1999	English

No.	Title	Language
55.	IODE Training on Oceanographic Data and Information Management for the Spanish-Speaking Countries of Central and South America / Curso de Formación del Iode sobre la gestión de datos e información oceanográficos para los países de habla hispana de América Central y del Sur Rio Grande, Brazil, 20-29 September 1999	English/Spanish
56.	*Cancelled*	
57.	PERSGA/ALECSO-IOC/GLOSS-GOOS Training Workshop on Sea-level Data Analysis for the red Sea and Gulf of Aden Region Jeddah, Kingdom of Saudi Arabia, 15-19 April 2000	English
58.	Third IOC/WESTPAC Training Course on NEAR-GOOS Data Management Tokyo, Japan, 24 January-4 February 2000	English
59.	Fourth IOC/WESTPAC Training Course on NEAR-GOOS Data Management; Tokyo, Japan, 27 November–8 December 2000 ***(electronic copy only)***	English
60.	First IOC-Flanders ODINAFRICA Training Course on Marine Data Management, Casablanca, Morocco, 2–13 April 2001 ***(electronic copy only)***	English
61.	First ODINAFRICA Training Course on Marine Information Management, Cape Town, South Africa, 29 October–9 November 2001 ***(electronic copy only)***	English
62.	First ODINCARSA Training Course on Marine Data Management, Guayaquil, Ecuador, 20-31 May 2002 ***(electronic copy only)***	English
63.	Remedial Training Course in Marine Data Management for Côte d'Ivoire, Abidjan, Côte d'Ivoire, 21-29 March 2002 ***(electronic copy only)***	English
64.	Second ODINAFRICA-II Training Course in Marine Data Management, Tunis, Tunisia, 29 April–10 May 2002 ***(electronic copy only)***	English
65.	***under preparation***	
66.	First ODINCARSA Training Course in Marine Information Management, Mazatlan, Mexico, 29 September – 4 October 2002 ***(electronic copy only)***	English & Spanish
67.	IODE Training Course in Ocean Data Management for the Caspian and Black Sea Regions, Tehran, I.R. Iran, 20–30 October 2002 ***(electronic copy only)***	English
68.	Fifth IOC/WESTPAC Training Course on NEAR-GOOS Data Management, Tokyo, Japan, 5–16 November 2001 ***(electronic copy only)***	English
69.	ODINAFRICA II Remedial Training Course in Marine Data Management (Data Short Course), Accra, Ghana, 14–18 April 2003 ***(electronic copy only)***	English
70.	Sixth IOC/WESTPAC Training Course on NEAR-GOOS Data Management, Tokyo, Japan, 21 October–1 November 2002 ***(electronic copy only)***	English
71.	Taller de Entrenamiento en Observación y análisis del Nivel del Mar, Valparaíso, 7-17 de abril de 2003 ***(disponible solamente en formato electrónico)***	Spanish
72.	ODINAFRICA II Combined Madagascar Marine Atlas Workshop and Remedial Training Course in Marine Data Management for Comoros, Tulear, Madagascar, 30 June – 11 July 2003 ***(electronic copy only)***	English
73.	ODINAFRICA II Training Course in Marine Data Management for Mozambique, Maputo, Mozambique, 11–22 August 2003 ***(electronic copy only)***	English
74.	Final ODINAFRICA II Training Course in Marine Data Management, Brussels, Belgium, 1–5 September 2003 ***(electronic copy only)***	English
75.	Second ODINCARSA Training Course in Marine Data Management, Cartagena, Colombia, 13–17 October 2003 ***(electronic copy only)***	English
76.	***under preparation***	
77.	IOC/JCOMM Training Course for the Global Sea Level Observing System (GLOSS) on Sea Level Observation and Analysis, 9–20 February 2004, Kuala Lumpur, Malaysia	English