INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
Training Course Reports

91

Electronic copy only

IOC/JCOMM/GLOSS/PRSN Caribbean Training Course for Operators of Sea Level Stations

23-27 June 2008
Mayagüez, Puerto Rico

UNESCO

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
Training Course Reports

91

IOC/JCOMM/GLOSS/PRSN Caribbean Training Course for Operators of Sea Level Stations

23-27 June 2008
Mayagüez, Puerto Rico

UNESCO 2008

IOC Training Course Report N° 91
Paris, 30 June 2008
English only

Abstract

This report provides a summary of the IOC-GLOSS-PRSN Caribbean Training Course for Operators of Sea Level Stations, which took place from June 23-27, 2008 in Mayagüez, Puerto Rico. The purpose of the course was to provide the sea level station operators in the region lectures and hands on training on the science and operations of sea level stations for tsunami and other coastal hazards warning purposes. It also considered the proposed IOCARIBE-GOOS partnership that promotes development and sustainability of the Caribbean Sea level array and its integration into the Caribbean Tsunami and Other Coastal Hazards Warning System. The report also provides an overview of methods and materials used for sea level observations, reports of national and regional sea level initiatives, and a set of recommendations concerning sea level activities in the region.

TABLE OF CONTENTS

1. INTRODUCTION

The UNESCO IOC Intergovernmental Coordinating Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) is responsible for coordinating the implementation of the Caribe EWS. One of the four components of the system is Monitoring and Warning Guidance. The need for sea level data in the Caribbean to suit operational and research needs was identified as a priority at the second and third session of the ICG Caribe EWS. Two of the mechanisms that have been recommended are (i) holding a training course for the operators of the sea level gauges in the region and (ii) supporting the IOCARIBE GOOS-GCOS Partnership for a Multi-Use Sea Level Observation Network for the Caribbean Region.

An important component of the Global Sea Level Observing System (GLOSS) is to provide training in sea level observation and data analysis for tide gauge operators. Since 1993 GLOSS has convened a course about once a year at different locations around the world. The core elements of these courses are: sea level observations, benchmark leveling, quality control, tidal prediction and underlining the requirements for long term high accuracy sea level measurements.

The Puerto Rico Seismic Network has expanded its roles and responsibilities since 2003 to include tsunami monitoring and warning guidance. As part of these expanded responsibilities the PRSN installed in 2008 six tsunami ready tide gauges in Puerto Rico to complement the ten sea level stations NOAA, currently operating in Puerto Rico and the US Virgin Islands. Nevertheless, the PRSN recognizes the need for a greater number of stations in the region providing timely and accurate sea level data. In recognition of this need the PRSN requested funding from NOAA to organize and conduct a sea level operator's workshop for the region.

2. LECTURES

The workshop program is provided in Annex I.

Opening and introduction to course

The workshop commenced at 8:30 am and the participants were welcomed by the following people:

Prof. Christa von Hillebrandt-Andrade, Director, Puerto Rico Seismic Network, UPRM. Prof. von Hillebrandt-Andrade welcomed the lecturers and participants of the course. She recognized the need for more sea level data for an effective warning system and how through this course the participants could contribute in closing this gap. She appreciated the support from United States, thrugh NOAA and other institutions which contributed to the funding of the course, UPRM and Government of Puerto Rico, thru PRSN, the Caribbean Regional Association for Coastal Observations (CARA), and GLOSS. The guidance of Mr. Bernardo Aliaga from the IOC Tsunami Unit and Dr. Thorkild Aarup, Technical Secretary of the Global Sea Level Observing System (GLOSS) was also recognized. She thanked Ms. Jeanette Lopez and Ms. Dalixza Irizarry for all the administrative arrangements.

Dr. Jorge Corredor, Co-PI ARCA, UPRM. Dr. Corredor expressed the honor it was for the Caribbean Regional Association for Coastal Observations (ARCA) to help support the Sea Level Course by funding Mr. Juan Fierro as a main lecturer. ARCA recognizes sea level observations as an important component of the system and although the area of responsibility of the Association is US Caribbean, they acknowledge and welcome opportunities to work and support other efforts in the Caribbean.

Mr. Bernard Kilonsky welcomed participants on behalf of GLOSS.

Mr. Thomas Landon, NOAA. He expressed NOAA's support for the workshop and hoped the course would lead to improved sea level observations in the Caribbean and adjoining regions.

Dr. Thomas Miller, Associate Director of the Geology Dept. In addition to welcoming the lecturers and participants, he recognized the importance of the data for providing timely warnings for tsunamis and coastal hazards, and its usefulness and applications in scientific research.

Mr. Israel Matos, Co-Chair, ICG-CARIBE EWS, UNESCO. He thanked the organizers, lecturers and attendees and also recognized the importance of improving sea level observations to achieve an effective Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions.

Dr. Moisés Orengo, Dean of the Faculty of Arts & Science. He welcomed the participants, wished them success and effective learning, and also an enjoyable stay in the Western region of Puerto Rico.

Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) (Mr. Israel Matos, Co-Chair, ICG-CARIBE EWS, UNESCO)

An overview was given on the history of the ICG Caribe EWS and the previous meetings which have been held in 2006, 2007, and 2008. He highlighted the recommendations on the establishment of a Regional Tsunami Warning Center, the Caribbean Tsunami Information Center, Hazards Assessment, Warning Dissemination and Communications and the budget for 2008-2009. The next ICG Caribe EWS meeting will be held in Martinique in March 2008.

Overview of GLOSS (Mr. Bernie Kilonsky, University of Hawaii Sea Level Center)

An overview was given on the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC), the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), the Global Ocean Observing System (GOOS) and the Global Sea Level Observing System (GLOSS). He highlighted regional developments, national activities and the training courses offered by GLOSS. One of the general recommendations of GLOSS is to establish regional projects to develop networks of modern sea level gauges linked to appropriate geodetic benchmarks. For further questions on GLOSS he directed the participants to contact the GLOSS Technical Secretary, Dr Thorkild Aarup and the Chair of the GLOSS Group of Experts, Dr. Mark Merrifield.

IOCARIBE GOOS-GCOS Partnership for a Multi-Use Sea Level Observation Network for the Caribbean Region (Mrs. Christa G. von Hillebrandt, Puerto Rico Seismic Network)

For the Caribbean Region the only sea level stations reporting sea level measurements in near real time are all located in Puerto Rico and the Virgin Islands, in addition to the NOAA DART buoys, 4 of which are in the Caribbean and adjoining regions. In order to be able to confirm whether a tsunami has been generated with potential impact, it has been recognized by ICG Caribe EWS that more real time sea level observations are required. The high priority sites recommended by ICG are Barbuda, Punta Manzanillo in Costa Rica, N, S and E coast of the Dominican Republic, Portobelo in Panama. The IOCARIBE GOOS-GCOS Partnership was explained as a mechanism for the operation of a Multi-Use Sea Level Observation Network for the Caribbean region

Introduction to Sea Level and Its Variations (Mr. Bernie Kilonsky, University of Hawaii Sea Level Center)

For this course the definition of sea level that would be used is the height of the sea measured relative to a mark on the nearby land called the tide gauge benchmark. The timescales for studying sea level changes vary from years to minutes. He presented seasonal and inter-annual changes for sea level due to water density. Tidal characteristics can be determined well from a year of good tide gauge data. The non tidal component of sea level was discussed. Sea level data are critical for the tsunami warning centers in issuing alerts or cancellations. He stressed the importance of having multi-purpose (as opposed to single purpose or “all hazards”) coastal sea level stations and data communications and the free and open exchange of real-time operational data. One of the proposed standards is that a sampling of 15 seconds averages and a continuous, or 1 minute transmission cycle for sites within 100 km of the tsunamigenic zones with immediate retransmission to the appropriate warning centers. The role of thermal expansion as one the contributors to rising sea level was discussed. Altimeters are also useful for observing sea level change but need to be validated with sea level stations.

Caribbean Oceanography (Dr. Jorge E. Corredor, University of Puerto Rico)

Dr Jorge Corredor gave an overview on the Caribbean circulation pattern, inter-annual and seasonal variability of river inflows, the temperature and salinity fields, eddies, tide patterns within the Caribbean (diurnal vs semi diurnal), density and internal waves. It is important to understand these phenomena and characteristics in evaluating variations in sea level in the region.

Instruments Used for Measurements of Sea Level (Mr. Bernie Kilonsky, University of Hawaii Sea Level Center)

The pros and cons for the following practices for observing sea level were presented: tide pole gauges, float gauges, acoustic gauges, pressure gauges, radar gauges. GLOSS requires that at least 5 benchmarks be installed near the gauge, one of which is the Tide Gauge Benchmark (TGBM) that should be leveled annually. There are many types of equipment, although the important issue is that the gauge be capable of measuring to at least a centimeter accuracy in all weather and wave conditions. He stressed the importance of a daily inspection of the data. The selection of tide gauge sites was also discussed.

Real-Time Data Transmission-GOES, Internet (Mr. Juan Fierro, Hydrographic and Oceanographic Service of the Chilean Navy)

Telemetry options include radio links, public switched telephone lines, mobile phone links and mobile satellite links. An overview of the traditional satellite systems available for real time transmissions were summarized: ARGOS, GOES E and W, POES, METEOSAT, MTSAT. Alternatives to satellite communications were discussed. More recent developments in telemetry include IRIDIUM, INMARSAT/BGAN, GLOBALSTAR, ORBCOMM. The service used depends on availability of channels, slots and costs. Developing an interface to GTS is important so that the data can be more accessible to the operational centers.

Hints for Optimum Installation and Operation of Tide Gauges (Mr. Bernie Kilonsky, University of Hawaii Sea Level Center)

Reference was made to the IOC Manual on Sea Level Measurement and Interpretation (Volume IV). Not all sites are suitable for meteorological purposes due to obstructions, but if they are appropriate, it is highly encouraged to add these types of sensors. He suggested that stations will have a tide pole gauge, even though they are not a primary source of sea level data. Float gauges, although tried and tested, have problems with stilling wells, density and require engineering of the site. Metadata needs to be provided for each of the stations. There is lots of expertise, especially large network, with acoustic gages with sounding tubes, which do require yearly calibration and some associated met sensors. He did not recommend open air acoustic gauges due to calibration issues. Pressure sensors can be used to create a solid data set, although it can be difficult to establish the datum. Pressure transducers are very survivable in high wave and storm conditions, but not as good for studies of long term sea level changes, unless datum control is exercised. Radar gauges are easily installed and economic. He reviewed recommendations for sensors, station and site selection.

Datum Control and Leveling (Mr. Juan Fierro, Hydrographic and Oceanographic Service of the Chilean Navy)

Mr. Juan Fierro addressed high precision GPS observations. GPS measurements can be corrected to obtain the absolute sea level variations. It is necessary to decouple sea level and land level datums. At each station datum needs to be established. Guidelines for benchmarks include taking into consideration its permanency and identification. Need to identify the gauge contact point. All the marks must be connected by leveling at least annually. Equipment includes automatic and digital levels, tripod, staff pole, change plate, pole staff bubble and survey markers. Need to take back sights, fore sights and intermediate sights. The acceptable disclosure error is established by the country for different classes. Most significant errors are from effect of earth curvature, refraction and collimation. Sea leveling measurements can be compared with altimetry measurements. If GPS is used, he recommended dual frequency with choke ring, better permanent, if not yearly observations would also be useful.

Sea Level Visualization Programs (Mr. Juan Fierro, Hydrographic and Oceanographic Service of the Chilean Navy)

Tide Tool program was presented. This software is managed by the Pacific Tsunami Warning Center available at ftp:ioc.unesco.org/ITIC/PTWC/Tide Tool. This tool display prints, creates error log and activates an alarm when PTWC or JMA issue a product which is automatically updated. Visualization tools permit the determination of arrival times of tsunamis and the amplitudes and periods. Vaisala software was also presented. Web tools from NOAA and IOC were also illustrated (www.vliz.be/gauges).

Tideview (Mr. Guy Urban, WCATWC)

An overview was given on how to get and display water level and DART data at the WCATWC. The main ways to obtain sea level data are thru GTS and via a browser. Additional pathways at WCATWC include NOAA net (only US), private internet provider, satellite and VSAT. Guy Urban emphasized the need to define for GTS and the local communications platform GTS message, GOES ID and WMO headers. He described the typical water level formats transmitted over GTS. Many different formats of data are transmitted on the GTS. He welcomed efforts to standardize data, like the CREX format. The data can be viewed on a web page or with graphic interface software such as TideTool (PTWC), Tide View (WCATWC) or the station monitoring (www.vliz.be/gauges). Disadvantage of the browser sites is that you can't take a measurement. He presented SOCKETPORT for decoding data and Tide View for displaying the data. It is a windows only program and there are plans for creating a Java script so it is platform independent.

Tide Monitoring Data System (Dr. Víctor Huérfano, Puerto Rico Seismic Network)

The web tools and decoders that have been developed and/or implemented at PRSN were presented.

Quality Control of Data (Mr. Bernie Kilonsky, University of Hawaii Sea Level Center)

Mr. Kilonsky first gave an overview of the 4 IOC Manuals on Sea Level Measurement and Interpretation (1985, 1994, 2000 and 2006). The need to have copies of the original data files was emphasized. He focused on processing and quality control aimed at producing hourly data. Be consistent with the use of tide gauge prediction programs. Convert the data to monthly data files and create yearly files.

DART II Buoys (Mr. Guy Urban, WCATWC)

An overview was given on the Deep Ocean Assessment for Reporting Tsunamis. There are five US NOAA DART II installed in the Caribbean and Adjoining Regions. The configuration, data availability and formats were discussed. There is a DART II set up in Mississippi to be used for training of tsunami warning center personnel. An overview was given on the data format and data types. Data can be accessed thru the RUDICS web page. The maintenance is usually given every 2 years. The batteries have enough power for 20 dial up events.

3. COUNTRY REPORT PRESENTATIONS

USA NOAA NOS [Thomas Landon and Allison Allen]

Maintenance and standards is the cornerstone of any program. Program description, end to end system of data collection, and national standard for legal certification explains the rigor of their operations such as NWLON attributes and NWLON Operations, NWLP support

TWX, Storm Surge Program and long term sea level studies, among others. NOAA is the lead agency for the US Tsunami Program, including warnings, research and observations. NOAA recognizes the need for tsunami hazard warning in the Caribbean. NOAA has hardened station installation in case of hurricanes. USA has a primary and backup system at every station. All stations transmit in 1 hour or 6 minute time slots via GOES and some sites are also using the IRIDIUM satellite system. Also perform short-term water level measurements. They operate an ocean systems test and evaluation program (OSTEP). Each station has a minimum of 10 benchmarks. Every year 2nd Order and Class 1 leveling is performed, and at least every two years all benchmarks are leveled. Some GPS stations observations are done annually or every 5 years depending on the rate of change, higher frequency is used when abnormal sea level change is observed. NOS and NGS have located CORS to establish whether the sea level change is associated with absolute sea level and subsidence. 24 x 7 quality assurance and control is conducted.

WCATWC [Guy Urban]

An overview was given on the operations of the West Coast Alaska Tsunami Warning Center. Access seismic and sea level data for decision process. In the case of an event more time is spent dedicated to analysis of sea level data than seismic data. WCATWC operates 9 tide gauge stations using VSAT for communications.

PUERTO RICO [Christa von Hillebrandt]

The Puerto Rico Seismic Network operates 24 seismic stations in the northeastern Caribbean monitoring 24 x 7 along with seismic data from another 50 seismic stations in the Caribbean and adjoining regions. The goal is to be able to detect earthquakes with Magnitude 4.5 or greater in the region within 1 minute in order to issue the corresponding earthquake/tsunami product within 5 minutes. Each station has an acoustic and pressure sensor. All data is transmitted in 6 minute slots thru GOES. A GOES ground station is located at the PRSN to access the data. XCONNECT and TideTool (WCATWC) are used to display the data. To complement the monitoring task, hazard and risk studies are conducted, as well as an education, preparedness and awareness program. Funding is provided mainly by the UPRM, Government of Puerto Rico and NOAA.

COSTA RICA [Fernando Urena]

RONMAC Program started in 2000 with NOAA funding after Hurricane Mitch. Currently, Red Observación Nivel del Mar de América Central, is only for Costa Rica. Costa Rica has installed stations on the Pacific and Caribbean coasts. The Limon station is operational but is not transmitting. The sample rate is every 6 minutes and it has a 3 hour time slot. The equipment consists of an Aquatrack logger/transmitter and a pressure sensor.

COLOMBIA [Leonardo Marriaga]

The Institute of Hydrology, Meteorology and Environmental studies directs and coordinates the environmental information system. The Oceanographic and Hydrographic Research Center from the General Maritime Directorate has been participating in the ICG and has the technical capability for observing, monitoring, prediction and alerts. It operates a network of wave buoys with meteorological capabilities, but none of the seven sea level stations transmit data in real time. Stations in the Caribbean are Cartagena, Capurgana, San

Andres (in front of the coast of Nicaragua) and del Rosario. Funding exists at present to acquire two stations for Tumaco and Gorgona Island in the Pacific. There are plans for four stations in the Caribbean.

SEISMIC RESEARCH CENTER [Nish Nath]

The efforts of SRC to monitor sea level have been focused on Kick "em Jenny. A tide gauge sensor was installed in 2001, but it was destroyed by wave action. SRC will be deploying two new instruments in Grenada by September, 2008.

TRINIDAD [Clinton Stewart]

Three stations were installed in Port of Spain and Point Fortin on Trinidad and Scarborough in Tobago. Due to timing the data were not received at UWI. Tide tables are compiled by the Proudman Oceanographic Laboratory. T & T has purchased 6 new gauges, 4 will be installed in Trinidad and 2 in Tobago and all gauges should be installed by 2008. These will be integrated into the current CPAC project and archived at CIMH in Barbados.

CCCCC (CIMH, BARBADOS) [Marvin Forde]

Eighteen original stations installed throughout the Caribbean. 2 stations were operational up to 2005, but not transmitting. In 2006 World Bank funding was obtained for 11 stations. CIMH will assist with the station installation, Regional Center to be located at CIMH, QA and QC for met data, pending for sea level data, provide technical assistance. Islands included now are Guyana, Barbados, Jamaica, Antin, St. Kitts, Antigua, Dominica, St. Lucia, Grenada, and St. Vincent.

BARBADOS [Ian Timothy]

Lack of local management and archival in Barbados has led to the unsustainability of the stations. Five stations have been installed in Barbados, only the gauge of the Coastal Zone Management Unit Pelican in Bridgetown is active and functioning well. No real time communications. CZMU operates a CORS. CZMU has another sea level station to install, in addition to the MAC station.

FRANCE [Arnaud Lemarchand]

Two stations in one in Martinique and Guadalupe with radar gauge and air pressure gauges. No real time transmissions. These are operated by the French Navy. Local authorities in Marnizieu installed on the east and another on the west. Geodetic leveling is always performed. GSM hourly transmission. IPGP has funding for 5 tide gauges in Guadeloupe. He presented sketches for the first station to be installed in La Desirades which will have a radar and air pressure sensors. Require a slot for GOES transmission because the station is GOES capable. Other communication platforms include RF links and VSAT. He requested recommendations on other measurements.

ANTIGUA AND BARBUDA [Donald Simon]

One station is operating in Antigua, Camp Blizzard. Operated by Fisheries Division and transferred to Antigua Meteorological Services. The station is operational, but does not have real time transmission of data. There are 3 benchmarks.

NETHERLAND ANTILLES AND ARUBA [Joeffrey Boekhudt]

Floating tide gauge and recorder installed in Curacao, access is limited to the Port Authority. Only paper records are available, no real time data. New installation is required to be managed by the National Met Service. Capacity building will be required.

BAHAMAS [Gregory Gibson]

Three stations were installed, two are operational. The operational stations are in Nassau and Lee Stocking Island. The stations transmit every three hours.

JAMAICA [Adrian Shaw]

Two tide gauges in Jamaica, south and north coast. Port Royal, data available from 1954 to 1971. There have been two stations at Discovery Bay, none are functional.

BRITISH VIRGIN ISLANDS [Nigel Cines]

In 1964 the Canadian Hydrographic Survey installed thee bench marks and operated a tide gauge station. The location of this station is now inland. A tide gauge station is under installation and will be contributing to the Caribe EWS.

DOMINICAN REPUBLIC (INDRHI) [Irving Baez]

INDRHI received funding to purchase 6 tide gauges. 44 gauges have been installed and, one was vandalized. The other three have onsite recording. Installation is pending for Santo Domingo and Punta Cana.

DOMINICAN REPUBLIC (ONAMET) [Claudio Martínez]

In the process of installing one tide gauge with the PRSN and ISU in Puerto Caucedo, Dominican Republic, along the southern coast. There is a GOES receiver at ONAMET, but it is not operational.

4. FIELD VISITS

The participants were invited to visit the NOAA Tide Gauge in “La Parguera”, Lajas, Puerto Rico. They were also taken to the Puerto Rico Seismic Network’s Sea Level Stations in Mayagüez and Arecibo and the NOAA’s Sea Level Station in Crash Boat in Aguadilla.

5. REVIEW, CONCLUSION AND RECOMMENDATIONS

In addition to the criteria established by GLOSS and outlined in the IOC Manuals I – IV, the SLO discussed and recommended a set of criteria and standards for the siting, sensors, leveling procedures, data processing and other factors for sea level stations in the Caribbean (Table 1).

SLO recognizes the efforts of many member states to install, operate and maintain sea level stations in the region to increase the availability of the sea level data and the importance of engaging the national and local governments. Nevertheless the SLO recognizes the lack of sea level stations in the region providing timely and accurate data for tsunamis and other coastal hazards purposes.

Recommend the establishment and maintenance of a digital web based sea level station book for the Caribbean and adjacent regions and appreciates the PRSN availability to perform this task.

It is very important for the sustainability of the stations that there be a sense of local ownership of the data and therefore the SLO supports efforts and programs for the local access and visualization to the sea level data.

Tsunamis and other coastal hazards do not recognize boundaries therefore the sea level network operators support free and open access of data.

The SLO supports the IOCARIBE-GOOS-GCOS Partnership to Support a Multi-Use Sea Level Observation Network for the Caribbean Region and urges the appropriate funding to be identified, and the active participation of the sea level operators. Priority should be given to document the definition of the Caribbean Tsunami hazard and risk. The SLO will engage the corresponding authorities in their countries to support the Partnership in the appropriate form.

SLO are concerned with the lack of time slots on GOES for real time transmission and request NESDIS for a channel for all the Caribbean Sea level stations or another appropriate alternative.

The SLO recognizes that a lot of expertise has been developed in the region and globally which should be taken full advantage of. Areas of support can include, but are not limited to, assistance with the determination of the siting and installation of the stations and training for data processing and visualization of sea level data. The SLO recommend venues to share sea level expertise, experiences, publications and reports. It was suggested that regional partners be included when installations are being performed and that a database on sea level expertise be created.

The sea level operators recognize that in addition to the necessity of timely and accurate sea level data, local emergency preparedness, education, mitigation, mapping and other monitoring efforts are needed to achieve an end to end tsunami and other coastal hazards warning system.

Table 1. Criteria and standards for the siting, sensors, leveling procedures, data processing and other factors for sea level stations in the Caribbean

Siting Criteria	
Tectonic/Geological	Stable. Co-located GPS would help determine the stability of the ground and help discriminate between the sea and land signals motions.
Support structure	Stable engineered structures are desirable. Hurricane and earthquake resistant
Wave activity	Avoid areas of high wave activity. The waves not only affect the operation of the station, also to the benchmarks.
River discharges	To be avoided when possible. Take into consideration when choosing instrumentation, consider using a radar if fresh water discharge is a problem.
Local Knowledge	Important to be taken into consideration, also to develop local ownership.
Development plans	Discuss future development plans that can affect the station
Tsunami	Determine possible travel time of tsunamis to the site.
Volcanic Activity	Having a portable station available to detect rapid sea level changes.
Documentation	Document the site selection process.
Decision Making process	Involve all the agencies that are interested and would be accessing the data
References	Historical and modeling data should be reviewed and taken into consideration.
Sensors and DCP	
Accuracy of sea level measurements	1 cm or less.
Sampling Rate	1 minute or less.
Data Format	Well documented, it will depend on the manufacturer. With height in mm, epoch time, check sum and metadata. Support standardization of data format, eg. CREX format for GTS.
Timing	GPS timing of data.
Power	Will be dependable on the sensors and DCP. Lowest as possible power consumption. Independent. Solar, wind power desirable. Backup power for 20 days for communications. Independent battery supply for communications and data collection. The capacity of the battery should be enough to support the communication requirements.
Calibration	As required to achieve the desired accuracy.
Reliability	Redundant sensors and DCP. On site storage capacity

Communications	
Transmissions	15 minutes or less. At sites tsunami travel times are less than 1 hour, higher frequency transmissions are required. Support efforts for event triggered communications with restricted access.
Robust	Reliable communications.
Accessibility	Data can be available to the corresponding institutions, warning centers.
Redundancy	Local and global communication systems. Overlap of data transmitted over satellites should be considered.
Format	Will be dependable on the communications platform. Needs to be well documented.
Two way communications	Desirable and highly recommended
Leveling	
Number of Bench marks	Minimum of five set.
GPS bench marks	Stable ground or engineered structures.
Location of benchmarks	Integrate existing bench marks. Install in stable areas. Locate in a variety of sites of geological and soil stability and engineered structures. Some perpendicular to the coast, not all parallel to the coast.
Leveling standard	Third order required, second order recommended.
Frequency of leveling	At least annually, or more often if ground is stable or after significant events that could affect the levels.
Continuous High Rate GPS	Recommended. Leveling must be performed between the primary benchmarks and the GPS at least annually.
Data Processing	
Inspection of Data	Daily.
Quality Control	Highly recommended.
Agencies	All the agencies that might require the sea level data should have access to the data, meteorological, navigation, research, seismic
Display of Data	Local real time displays for the sea level operators are required, eg. Tide Tool, Tide View, or IOC Sea Level Station Monitoring Facility.
Format of Data	Well documented. With height in mm, epoch time, check sum and metadata. Support standardization of data format, eg. CREX format for GTS.
Other Factors	
Local operators	Expertise in formatting, leveling, electronics and oceanography.
Funding	Redundant funding is required for the operation of the stations. Seek reduced special rates for communications in consideration of the emergency applications.

Training	Necessary. Sharing of publications and reports and training opportunities.
Maintenance Schedule	Yearly visits are required.
Replacement of equipment	Overlap of time period sensors are operating.
Communications with Emergency Management authorities	Direct and robust communications between the institutions monitoring sea level data, warning centers and the emergency management institutions.

6. CLOSURE

On Friday 27 June 2008, the Chancellor of the University of Puerto Rico at Mayagüez delivered a greeting to the attendees of the course. A group picture was taken with the Chancellor. The Sea Level training course was officially closed by Christa G. von Hillebrandt-Andrade. Leonardo Marriaga Rocha, Oceanographer of the Oceanographic and Hydrographic Research Center of Colombia, on behalf of the participants thanked the Puerto Rico Seismic Network for the excellent organization and conduct of the course. Certificates (Appendix IV) were distributed by Christa von Hillebrandt, Bernard Kilonsky and Juan Fierro and the workshop was closed at 6:30 on Friday, June 27, 2008.

7. ACKNOWLEDGMENTS

Support for this training course was provided by the US Government, NOAA, the University of Puerto Rico and the Government of the Commonwealth of Puerto Rico thru the Puerto Rico Seismic Network. Funding for the lecturers was provided by IOC (Bernard Kilonsky) and the Caribbean Regional Association for Coastal Observations, CARA (Juan Fierro).

ANNEX I

COURSE SCHEDULE

Date/Day	Time	Program/Activity	Lecturer
Mon. 23 June 2008	8:00am – 8:30am	Registration	
	8:30am – 9:00am	Official Opening	
	9:00am – 9:15am	Group Photo	
	9:30am – 9:40am	Presentation of Attendees	Christa von Hillebrandt
	9:40am – 10:30am	Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS)	Israel Matos
	10:30am – 11:15am	GLOSS	Bernie Kilonsky
	11:15am to 12:00n	IOCARIBE GOOS-GCOS Partnership for a Multi-Use Sea Level Observation Network for the Caribbean Region	Christa von Hillebrandt
	1:00pm – 3:00pm	Introduction to Sea Level and Its Variations	Bernie Kilonsky
	3:15pm – 4:00pm	Caribbean Oceanography	Jorge Corredor
	4:00pm – 5:30pm	Instruments Used for Measurement of Sea Level	Bernie Kilonsky
Tue. 24 June 2008	8:00am – 10:00am	Real-Time Data Transmission-GOES, Internet	Juan Fierro
	10:30am – 12:00n	Hints for Optimum Installation and Operation of Tide Gauges	Bernie Kilonsky
	1:00pm – 2:30pm	Datum Control and Leveling	Juan Fierro
	2:30pm – 3:15pm	Sea Level Instrumentation Country Reports	Attendees
	3:30pm – 4:00pm	Sea Level Instrumentation Country Reports	Attendees
	4:00pm – 5:00pm	Visit to the Puerto Rico Seismic Network	Attendees
Wed. 25 June 2008	8:00am – 10:00am	Sea Level Visualization Programs	Juan Fierro
	10:30am – 12:00n	Tideview	Guy Urban Víctor Huérfano
	1:00pm – 3:00pm	Sea Level Instrumentation Country Reports	Attendees
	3:15pm – 5:00pm	Sea Level Instrumentation Country Reports	Attendees
	5:00pm	Visit to NOAA Tide Gauge, Tour of the	Juan González Lagoa

		Phosphorescent Bay, Parguera, Lajas.	
Thu. 26 June 2008	8:00am	Field Trip	
Fri. 27 June 2008	8:00am – 10:00am	Quality Control of Data	Bernie Kilonsky
	10:15am – 11:15am	DART Buoys	
	11:15am – 12:00n	Review, conclusion and recommendations	Attendees
	1:00pm – 3:15pm	Review, conclusion and recommendations	Attendees
	3:30pm – 4:00pm	Closure	

ANNEX II

COURSE MATERIAL

List of course materials used during the course.

- D. Pugh (2004): Changing Sea Levels.
- IOC Manual 14 on Sea Level Measurement and Interpretation: Volume IV: An update to 2006.
- S. Dopp-Hicks (2006): Understanding Tides. NOAA.
- Tsunami Warning Center Reference Guide Software 2007.

ANNEX III

LIST OF PARTICIPANTS

TRAINEES

Allen, Allison
NOAA National Ocean Service
Oceanographer
1305 East West Highway, #7234
Silver Spring, MD 20910
USA
Tel (W): 301-713-2890 Ext 166
Tel (H): 240-638-6882
Fax: 301-713-4437
Email: allison.allen@noaa.gov

Anselmi-Molina, Carlos M.
Caribbean Regional Association (CARA)
University of Puerto Rico
Graduate Student
Mayagüez, PR 00681
Puerto Rico
Cell: 939-245-1775
Email: carlos.anselmi@uprm.edu

Arnaud, Lemarchand
Institut de Physique du Globe de Paris
Chief Engineer of Volcano Observatories
4 Place Jussieu 75252
Paris
France
Tel: 33 1 44 27 48 13
Fax: 33 1 44 27 24 01
Email: arnaudl@ipgp.jussieu.fr

Báez Morillo, Irving
National Institute of Hydraulic Resource
Chief of Electronic Instrumentation Division
Juan de Dios Ventura Avenue, Apat. 1407
Santo Domingo
Dominican Republic
Tel (W): 809-532-3271, Ext. 3464
Tel (H): 809-496-5830 and 809-616-9716
Fax: 809-508-7215
Email: irvinmorillo@hotmail.com

Báez Sánchez, Gisela
Puerto Rico Seismic Network
University of Puerto Rico
Coordinator, Geophysical Data Analyses
PO Box 9017, Mayagüez, PR 00681
Puerto Rico
Tel: 787-833-8433
Cell : 787-464-0341
Fax: 787-265-1684
Email: gbaez@midas.uprm.edu

Boekhoudt, Joffrey
Meteorological Service of the Netherlands Antilles and Aruba
Climate Research and Development
Mahuma, Curacao
Netherlands Antilles
Tel (W): 05999-839-3368 or 839-3328
Tel (H): 564-6241
Email: joffrey.boekhoudt@gov.an and boekhoudt@hotmail.com

Brown, Kevin
Center for Marine and Environmental Studies
University of Virgin Islands
Research Specialist
2 John Brewer's Bay, St. Thomas, VI 00802
USA
Tel: 340-693-1384
Fax: 340-639-1385
Email: kbrown@uvi.edu

Caines, Nigel
Survey Department, BVI Government
CAD Technician
Road Town, Tortola, BVI
British Virgin Islands
Tel (W): 284-494-3459
Tel (H): 284-494-2942
Fax: 284-494-3895
Email: survey@bvigovernment.org and ncainz@hotmail.com

Cano, Leonardo
Puerto Rico Seismic Network
University of Puerto Rico
Graduate Student
PO Box 9017
Mayagüez. PR 00681
Puerto Rico
Tel: 787-833-8433
Cell: 787-238-5328
Fax: 787-265-1684
Email: lcano@midas.uprm.edu

Cole, George
Department of Civil Engineering & Surveying
University of Puerto Rico
Visiting Prof. of Surveying & Topography
PO Box 9041
Mayagüez, PR 00681
Puerto Rico
Tel (W): 787-265-5405
Tel (H): 850-544-3806
Fax: 787-833-8260
Email: gcole@uprm.edu

Ferrer, Fernando
Puerto Rico Seismic Network
University of Puerto Rico
Chief Data Analyst
PO Box 9017
Mayagüez, PR 00681
Puerto Rico
Tel: 787-833-8433
Cell: 787-349-0688
Fax: 787-265-1684
Email: fferrer@midas.uprm.edu

Forde, Marvin
Caribbean Institute for Meteorology & Hydrology (CIMH)
Technical Officer (1)
Husbands, St. James, BB23006
Barbados
Tel (W): 246-425-1362 and 246-425-1365
Tel (H): 246-435-0745
Fax: 246-424-4733
Email: mforde@cimh.edu.bb

Gibson, Gregory G.
Department of Meteorology
Trainee Meteorological Officer
PO Box 8330
Nassau N.P.
Bahamas
Tel (W): 242-356-3736 and 242-377-7461
Tel (H): 242-324-3321
Cell: 242-456-6524
Fax: 242-356-3739 and 242-377-1750
Email: gregory_gibson_25@hotmail.com and gregory_gibson_1969@yahoo.com

González, Juan O.
Department of Marine Sciences
University of Puerto Rico
Graduate Student – Physical Oceanography
Mayagüez, PR 00681
Puerto Rico
Cell: 787-356-7057
Email: ocean.gonzalez@gmail.com

Hernández, Alice
Puerto Rico Seismic Network
University of Puerto Rico
Graduate Student
PO Box 9017
Mayagüez. PR 00681
Puerto Rico
Tel: 787-833-8433
Cell: 787-640-7194
Fax: 787-265-1684
Email: ahernandez@midas.uprm.edu

Hincapié Cárdenas, Carolina
Puerto Rico Seismic Network
University of Puerto Rico
Graduate Student
PO Box 9017
Mayagüez. PR 00681
Puerto Rico
Tel (W): 787-833-8433
Tel (H): 787-477-5679
Fax: 787-265-1684
Email: chincapie@midas.uprm.edu

Irizarry, Harold J.
Puerto Rico Seismic Network
University of Puerto Rico
Chief Data Analyst
PO Box 9017, Mayagüez, PR 00681
Puerto Rico
Tel: 787-833-8433
Fax: 787-265-1684
Email: hirizarry@midas.uprm.edu

Landon, Thomas
NOAA National Ocean Service
National Water Level Program Lead
1305 East West Highway, SSMC4
Sta. 6409, Silver Spring, MD 20910
USA
Tel (W): 301-713-2897 Ext 191
Cell: 301-461-8063
Fax: 301-713-4465

Marriaga Rocha, Leonardo
Oceanographic & Hydrographic Research Center
Operational Oceanography Area
Cartagena
Colombia
Tel: 6694104
Cell: 300-8167379
Email: lmarriaga@dimar.mil.co

Martínez Jiminian, Claudio
National Meteorology Office (ONAMET)
OMMIV Observer and Radar Expert
Juan Molina #1 St., Los Mameyes
Santo Domingo
Dominican Republic
Tel (W): 809-788-1122
Tel (H): 829-779-0818
Fax: 809-597-9842
Email: claudiomartin85@hotmail.com

Nath, Nisha
The Seismic Research Centre Unit, U.W.I.
Chief Technician – Seismology
St. Augustine Campus
Trinidad and Tobago
Tel (W): 868-662-4659
Tel (H): 868-760-0646
Fax: 868-663-9293
Email: seismictech@uwiseismic.com and nisha_nath@yahoo.com

Pujols, Rafael
Puerto Rico Seismic Network
University of Puerto Rico
Graduate Student
PO Box 9017
Mayagüez. PR 00681
Puerto Rico
Tel (W): 787-833-8433
Fax: 787-265-1684
Email: rpujols@midas.uprm.edu and rafaelpujols@hotmail.com

Shaw, Adrian
Meteorological Service, Jamaica
Meteorologist
65 ¾ Half Way Tree Road, Kingston 10
Jamaica
Tel (W): 929-3700 and 929-3706
Tel (H): 969-6002 and 362-3017
Fax: 960-8989
Email: metservice.cbh@jamweb.net and balleryouth@hotmail.com

Santiago, Javier
Puerto Rico Seismic Network
University of Puerto Rico
Scientific Instrumentation Specialist
PO Box 9017, Mayagüez. PR 00681
Puerto Rico
Tel (W): 787-833-8433
Tel (H): 787-868-2750
Fax: 787-265-1684
Email: santiagoj@midas.uprm.edu

Román, Yomayra
Puerto Rico Seismic Network
University of Puerto Rico
Chief Data Analyst
PO Box 9017, Mayagüez, PR 00681
Puerto Rico
Tel: 787-833-8433
Cell: 787-632-8256
Fax: 787-265-1684
Email: yomroman@midas.uprm.edu

Simon, Donald
Antigua Meteorological Services
Information Systems Manager
V.C. Bird Int'l Airport, Coolidge
PO Box 1051
Antigua
Antigua and Barbuda
Tel (W): 268-462-3229 and 268-462-4606
Tel (H): 268-460-4503
Fax: 268-462-4606
Email: metoffice@antigua.gov.ag and don_acs@yahoo.com

Soto, Lillian
Puerto Rico Seismic Network
University of Puerto Rico
Chief Data Analyst
PO Box 9017
Mayagüez, PR 00681
Puerto Rico
Tel (W): 787-833-8433
Tel (H): 787-877-0341
Fax: 787-265-1684
Email: lsoto@midas.uprm.edu

Stewart, Clinton R.
Survey & Mapping Division
Hydrographic Surveying Assistant
118 Frederick St.
Port of Spain
Trinidad and Tobago
Tel (W): 868-627-9201 and 868-627-9204
Tel (H): 868-674-0235
Cell: 868-756-7337
Email: disd@tstt.net.tt and clintons@tstt.net.tt

Timothy, Ian G.D.
Coastal Zone Management Unit
Field Inspector
Bay Street, St. Michael
Barbados
Tel (W): 246-228-5950 and 246-228-5951
Fax: 246-228-5956
Email: itimothy@coastal.gov.bb

Ureña Elizondo, Fernando
International Ocean Institute
Ronmac Sea Level Stations Technical Coordinator
National University
Heredia
Costa Rica
Tel (W): 506-2-277-3594
Tel (H): 506-8-838-9487
Fax: 506-2-260-2546
Email: furenae@gmail.com

Vélez, Linda
Department of Civil Engineering & Surveying, University of Puerto Rico
Professor
PO Box 9041
Mayagüez, PR 00681
Puerto Rico
Tel (W): 787-265-5405
Tel (H): 787-313-4740
Fax: 787-833-8260
Email: velezl@uprm.edu

LECTURERS

Corredor, Jorge E.
Department of Marine Sciences
University of Puerto Rico
PO Box 9041
Mayagüez, PR 00681
Puerto Rico
Tel: 787-899-2048 Ext. 244
Email: jcorredor@uprm.edu

Fierro, Juan
Hydrographic & Oceanographic Service of the Chilean Navy
Oceanography Department
Director, Physical Oceanography Section
Chile
Tel: 56 32 2266676
Fax: 56 32 2266542
Email: jfierro@shoa.cl

Huérfano, Víctor A.
Puerto Rico Seismic Network
University of Puerto Rico
Aux. Researcher, PO Box 9017
Mayagüez. PR 00681
Puerto Rico
Tel (W): 787-833-8433
Fax: 787-265-1684
Email: victor@midas.uprm.edu

Kilonsky, Bernard
University of Hawaii
Sea Level Center, 1000 Pope Rd.
Honolulu, HI 96822
USA
Tel: 808-956-6574
Email: kilonsky@hawaii.edu

Matos, Israel
ICG-CARIBE EWS, UNESCO
Vice-Chair ICG
Meteorologist in Charge
NOAA/ National Weather Service
Forecort Office
Carretera 190 N°. 4000 Carolina, P.R
USA
Tel: (787) 253-4586 Ext. 222
Fax: (787) 253-7802
E-mail: israel.matos@noaa.gov

Urban, Guy W.
West Coast/Alaska Tsunami Warning Center
Geophysicist
910 South Felton
Palmer, AK 99645
USA
Tel (W): 907-745-4212
Tel (H): 907-746-1310
Fax: 907-745-6071
Email: guy.urban@noaa.gov

von Hillebrandt, Christa
Puerto Rico Seismic Network
Director
PO Box 9017, Mayagüez. PR 00681
Puerto Rico
Tel (W): 787-833-8433
Tel (H): 787-805-0447
Cell: 787-608-2577
Fax: 787-265-1684
Email: christa@midas.uprm.edu

SUPPORT STAFF

Feliciano, Angel
Computer Technician
Puerto Rico Seismic Network
PO Box 9017
Mayagüez, PR 00680
Puerto Rico
Tel: 787-833-8433
Fax: 787-265-1684
Email: angel@midas.uprm.edu

Irizarry, Dalixza
Secretary
Puerto Rico Seismic Network
PO Box 9017
Mayagüez, PR 00680
Puerto Rico
Tel: 787-833-8433
Fax: 787-265-1684
Email: dalixza@midas.uprm.edu

Lucena, Celestino
Worker
Puerto Rico Seismic Network
PO Box 9017
Mayagüez, PR 00680
Puerto Rico
Tel: 787-833-8433
Fax: 787-265-1684
Email: c.lucena@midas.uprm.edu

López, Jeanette
Administrative Assistant
Puerto Rico Seismic Network
PO Box 9017
Mayagüez, PR 00680
Puerto Rico
Tel (W): 787-833-8433
Tel (H): 787-832-1094
Cell: 787-249-8515
Fax: 787-265-1684
Email: jeanette@midas.uprm.edu

ANNEX IV

CERTIFICATE


THE INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION OF UNESCO
THE PUERTO RICO SEISMIC NETWORK, DEPARTMENT OF GEOLOGY
UNIVERSITY OF PUERTO RICO AT MAYAGÜEZ

Herewith certify that

Attended and successfully completed the

UNESCO/IOC ICG CARIBE EWS
CARIBBEAN TRAINING COURSE FOR OPERATORS OF SEA LEVEL STATIONS

Organized by the Puerto Rico Seismic Network

Mayagüez, Puerto Rico
June 23-27, 2008

Dr. Bernie Kilonsky
Sea Level Center University of Hawaii
GLOSS

Israel Matos
Co-Chair
ICG-CARIBE EWS, UNESCO

Juan Fierro
Navy Hydrographic and Oceanographic Services
Chile

Christa von Hillebrandt-Andrade
Director
Puerto Rico Seismic Network

ANNEX V

GROUP PHOTO

ANNEX VI

ACRONYMS

CARIBE EWS	Caribbean Early Warning Systems
GCOS	Global Climate Observing System
GLOSS	Global Sea Level Observing System
GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
ICG	International Centre for Geohazards
IOC	Intergovernmental Oceanographic Commission
IOCARIBE	Intergovernmental Oceanographic Commission – Sub Commissions for the Caribbean and Adjacent Regions
NOAA	National Oceanic and Atmospheric Administration
PRSN	Puerto Rico Seismic Network
UNESCO	United Nations Educational, Scientific and Cultural Organization

ANNEX VII

BACKGROUND REPORTS AND PRESENTATIONS

No.	Title	Language
1.	Report to the IOC-GLOSS-PRSN on the Status of the Tide Gauge/Sea Level Monitoring Station in Antigua.	English
2.	National Report for the Bahamas.	English
3.	Report on the National Tide Gauge Network of Barbados.	English
4.	British Virgin Islands Sea Leveling Status.	English
5.	Colombian Sea Level Network: Current Status.	English & Spanish
6.	Costa Rica's Report on the Local Sea Level Monitoring System.	English
7.	Sea Level Data From Cuban Sea Level Stations to Permanent Service for Mean Sea Level (PSMSL).	English
8.	National Report on Sea Level Status in Jamaica.	English
9.	Puerto Rico Tsunami Ready Tide Gauge Network.	English
10.	Estatus Mareógrafos en República Dominicana, Instituto Nacional de Recursos Hidráulicos (INDRHI)	Spanish
11.	National Report of the Republic of Trinidad and Tobago 11th Session of the Group of Experts for the Global Sea Level Observing System (GLOSS)	English
12.	Sea Level Monitoring at the Seismic Research Unit	English
13.	Caribbean Oceanography, Jorge E. Corredor	English
14.	Global Level of the Sea Surface, The Future of Operational Oceanography, Bernard Kilonsky	English
15.	Global Level of the Sea Surface, Permanent Service for Mean Sea Level, Bernard Kilonsky	English
16.	Methods For Sea Level Measurement, Bernard Kilonsky	English
17.	Sea Level Variations, Bernard Kilonsky	English
18.	Tsunami and Other Coastal Hazards Warning System for the Caribbean Sea and Adjacent Regions (IOC/ICG CARIBE EWS), Israel Matos	English

19.	Partnership for a Multi-Use Sea Level Observation Coordination Network for the Caribbean Region, Christa G. von Hillebrandt-Andrade	English
20.	Datum Control and Leveling, Juan J. Fierro	English
21.	Real Time Data Transmission, Juan J. Fierro	English
22.	Sea Level Data and Its Application at the West Coast/Alaska Tsunami Warning Center, Guy Urban	English
23.	Sites and operations, Bernard Kilonsky	English
24.	NOAA's National Water Level Program Overview, Thomas F. Landon, and Allison Allen	English
25.	National Report of Curaçao	English
26.	French West Indies Sea Level instrumentations, Arnaud Lemarchand	English
27.	Specifications of tide gauge at "La Désirade"	English
28.	Getting and Displaying Water Level and DART Data at WCATWC, Guy Urban	English
29.	Mareógrafo en Republica Dominicana, ONAMET	Spanish
30.	Report on the Re-establishment Of the Sea Level Monitoring For the English-speaking Caribbean	English
31.	Sea Level Visualization Programs, Juan Fierro	English
32.	Tide Monitoring Data System, Víctor Huérfano	English
33.	DART II, Guy Urban	English