UPDATE ON SEA LEVEL NETWORK DEVELOPMENTS OF THE INTERGOVERNMENTAL COORDINATION GROUP FOR THE TSUNAMI AND OTHER COASTAL HAZARDS FOR THE CARIBBEAN AND ADJACENT REGIONS (ICG/CARIBE EWS)

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Introduction

The UNESCO IOC Intergovernmental Coordinating Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE EWS) is responsible for coordinating the implementation of the Caribbean Tsunami Warning System. The need for sea level data in the Caribbean to suit operational and research needs was identified as a priority for the forecasting and detection of tsunamis and other coastal hazards.

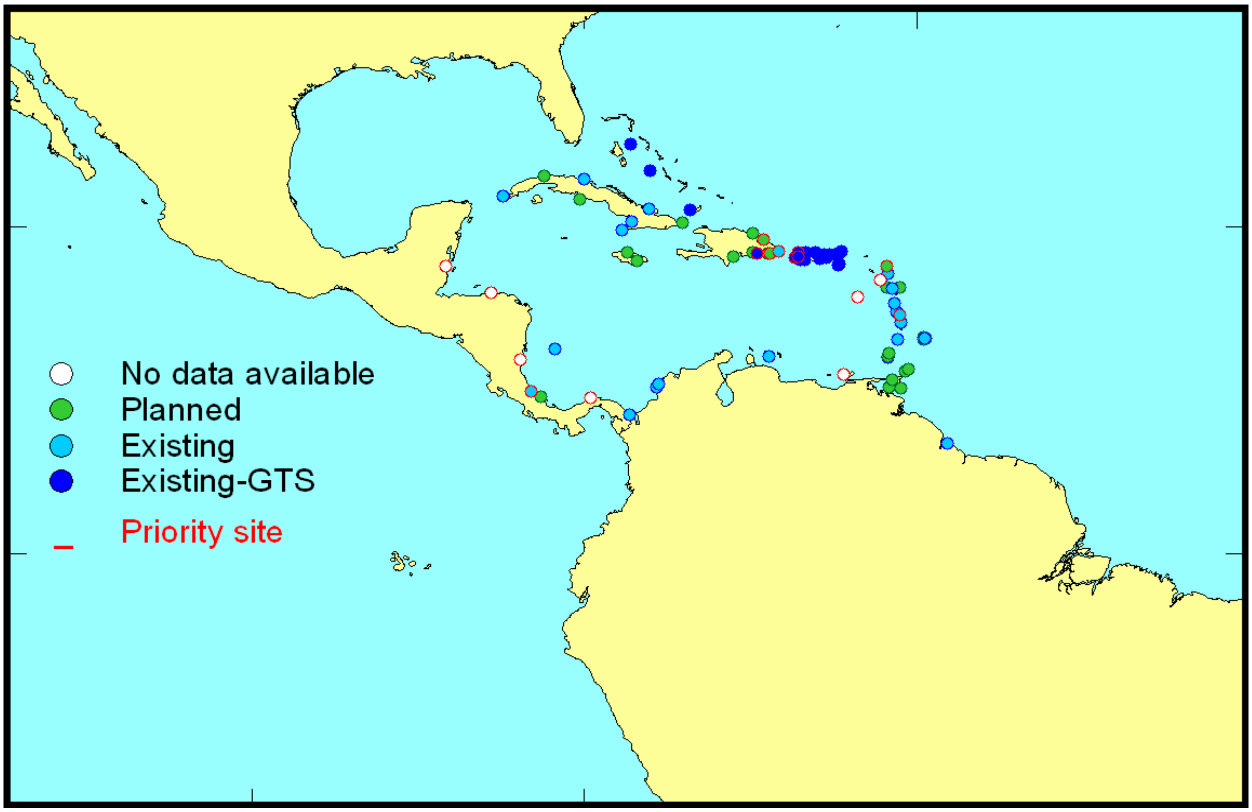
The ICG/CARIBE EWS Working Group I on Monitoring and Detection Systems and Warning Guidance was established in 2007. Its purpose is to review and recommend to the ICG priorities and actions required towards the full establishment of a coordinated regional tsunami warning system. During its meetings and intersessional periods it maintains an inventory of the sea level stations and monitoring capabilities of the region. In 2008 an IOC-GLOSS-PRSN Caribbean Training Course for Operators of Sea Level Stations was hosted by the Puerto Rico Seismic Network in Mayaguez, Puerto Rico. This report will present a summary of these activities.

Status of Sea Level Monitoring and Capabilities in the Caribbean

Over the past 20 years, some 70 sea level gauge stations have been installed in the Caribbean and surrounding countries by CPACC (Caribbean Planning for Adaptation to Global Climate Change), RONMAC (Water Level Observation Network for Latin America) NOAA and other locally and internationally-funded programs. Initially most of the stations were installed to examine local and regional sea level changes associated with climate change. More recently major driving forces are tsunamis and other coastal hazards. As of February 2006, most stations were in various states of disrepair, the majority of which no longer collected data, and in many cases, installations were missing equipment (Henson, 2006). Presently several efforts are underway to install, replace and repair sea level stations. The UNESCO IOC Intergovernmental Coordinating Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE EWS) has focused on sea level stations for tsunamis and other coastal hazards early warning system applications.

The ICG/CARIBE EWS Working Group I on Monitoring and Detection Systems and Warning Guidance has identified 44 operational sea level stations of the region, 17 of these are contributing sea level data within 15 minutes thru GOES, a requirement of the CARIBE EWS (Figure 1). Most of the TsunamiReady sea level stations are located in Puerto Rico and the US Virgin Islands and are operated by NOAA and the Puerto Rico Seismic Network. Another TR station is located along the southern coast in the Dominican Republic, it was funded by the US

Government and is operated jointly by the National Office of Meteorology of the Dominican Republic and the PRSN. Bahamas has three operational stations but their time slots are 3 hours, not appropriate for EWS. The British Virgin Islands finished installing a station during 2008, and although the data is transmitting over GOES, due to format issues the data have not been integrated into the TWS. France is in the process of uploading into GOES in 5 minute time slots data from 2 stations in Guadeloupe and Martinique. During 2008-2009 the Caribbean Institute for Hydrology and Meteorology (Barbados) has installed 7 of 8 tide gauges [Antigua, Barbados, Dominica, Grenada, Guyana, St. Kitts, St. Lucia, St. Vincent, St. Kitts (pending)] for the Caribbean Community Climate Change Centre (CCCCC). These stations are not transmitting in real time, and the plans for this are not clear. In other countries of the region there are stations that are operational but not transmitting in real/near real time or not operational. In the 2008 many of the participants of the IOC-GLOSS-PRSN Caribbean Training Course for Operators of Sea Level Stations, reported on plans to install and upgrade sea level stations (Appendix 1 and 2).



Henson et al (2006) examined the potential impact of past Caribbean tsunamis generated by earthquakes and/or massive submarine slides/slumps, as well as the tsunamigenic potential and population distribution within the Intra-Americas Sea (IAS) to help define the optimal location for coastal sea level gauges. The goal of the study was to identify the minimum number of sea level gauge locations to aid in tsunami detection and provide the most warning time to the largest number of people. 12 initial, prioritized locations for coastal sea level gauge installation were identified. These stations were recognized by the Caribe EWS as high priority stations with a recommendation that funding be identified for their installation and operation (Appendix 1). Of these, three are operational and transmitting over GOES within 6 minutes (Puerto Rico (2) and

Dominican Republic) and one is pending the GOES activation. For several of the other stations proposals have been submitted. Additional stations, defined with an (*) in Appendix 1 have been defined as high due to its strategic location near an active volcano that has been considered to have the potential to generate tsunamis and on islands within the Caribbean Sea.

In addition to the 12 high priority sites of the Caribe EWS, support has been sought to integrate other planned and existing stations into the core Caribe sea level network. These additional stations would reduce the time to detect and forecast tsunamis and other coastal hazard impact. The full list of existing, existing with near real time transmission (RTX) and planned stations is in Appendix 1. A list of sea level network operators is in Appendix 2.

One of the issues identified in the Caribbean was the lack of GOES channels with at least fifteen minute time slots. In 2008, NOAA NESDIS made available to the CARIBE EWS a GOES channel for the transmission of sea level data. These slots will be assigned to Caribbean stations installed or ready for installation as 10 second packets transmitted every 5 minutes (10/5). When 80% of these slots are assigned, WG1 will reconsider the strategy of assigning GOES slots.

The attendees of the Sea Level Operators workshop in 2008, recognized 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. NOAA, thru the PRSN, has provided funding for this type of support as of 2008.

Other recommendations of the Sea Level Operators course included:

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 (Appendix 3).

SLO recognized 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 also recognized the lack of sea level stations in the region providing timely and accurate data for tsunamis and other coastal hazards purposes.

Recommended 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 supported 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 supported free and open access of data.

The SLO supported 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.

The sea level operators recognized 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.

References

Henson, J., Muller-Karger, F., Wilson, D., Morey, S., Maul, G., Luther, M., Kranenburg, C., 2006. Strategic Geographic Positioning of Sea Level Gauges to Aid in Early Detection of Tsunamis in the Intra-Americas Sea, Science of Tsunami Hazards, Vol. 25, No. 3, pp. 173-207.

IOC, 2008. IOC-GLOSS-PRSN Caribbean Training Course for Operators of Sea Level Stations, June 23-27, 2008, Mayagüez, Puerto Rico.

Appendix 1

Core Sea Level Stations in the Caribbean (May, 2009)

Station location	Country	Lat	Long	Date installed	Priority	Status	Operator	GOES ID	Collocated GPS
Camp Blizzard/Parham	Antigua	17.1583	-61.7833		Medium	Existing	Antigua & Barbuda Met. Services		
				2009		Existing	MACC	In request	
Nassau Harbour, New Providence	Bahamas	25.05	-77.22	Apr-98	Medium	Existing	Bahamas Dept. of Meteorology	941-001	
Lee Stocking Island, Exuma	Bahamas	23.46	-76.06	Apr-98	Medium	Existing	Bahamas Dept. of Meteorology	941-002	
Matthew town, Inagua	Bahamas	21.05036	-73.647	May-98	Medium	Gap	Bahamas Dept. of Meteorology	941-003	
Pelican Fort	Barbados	13.19388	-59.5432	2007	Medium	Existing	CPACC?		
Willoughby Fort	Barbados	13.1	-59.6166	1983/1990	Medium	Planned	Coastal Zone Management Unit		
Conset Bay, Barbados	Barbados	13.183	-59.467	1997	Medium	Planned	Coastal Zone Management Unit		
Harbour, Barbados	Barbados	13.1	-59.6166	1998	Medium	Planned	CPACC		
Speightstown, Barbados	Barbados	13.25028	-59.65	2002	Medium	Planned	Coastal Zone Management Unit		
Bridgetown/MACC project	Barbados	13.1	-59.62	2009	Medium	Existing	Meteorological Service	In request	
Barbuda	Barbuda	17.61667	-61.8		High	Planned	NOS/NOAA		
Belize	Belize	17.5741	-88.3704		Medium	Gap			
Road Town Harbor, Tortola	British Virgin Islands	18.5	-64.55	1964	Medium	Existing	Survey Dept.	**B110070A**	
Cartagena,	Colombia	10.3914	-75.5369		Medium	Existing	IDEAM		
San Andres	Colombia	12.55	-81.7667		High*	Existing	IDEAM		
Islas del Rosario	Colombia	10.1834	-75.6667		Medium	Existing	IDEAM		
Capurganá	Colombia	8.5162	-77.3283		Medium	Existing	IDEAM		
Juanchaco	Colombia	3.9236	-77.3283		Medium	Existing	IDEAM		
Buenaventura	Colombia	3.8903	-77.0622		Medium	Existing	IDEAM		
Isla Tesoro	Colombia	10.2495	-75.7377	2009		Planned	INVEMAR		

Johnny Cay		12.5993	81.6894	2009		Planned	INVEMAR		
Limón	Costa Rica	9.9	-83.2		High	Existing	RONMAC		
Gibara,	Cuba	21.1083	-76.125		Medium	Existing	Of.Nacional Hidrografía y Geodesia		
Cabo Cruz	Cuba	19.84	-77.7283		Medium	Existing	Of.Nacional Hidrografía y Geodesia		
Isabela de Sagua	Cuba	22.94	-80.0133		Medium	Existing	Of.Nacional Hidrografía y Geodesia		
Cabo San Antonio	Cuba	21.9	-84.9067		Medium	Existing	Of.Nacional Hidrografía y Geodesia		
Manzanillo	Cuba	20.34	-77.1467		Medium	Existing	Of.Nacional Hidrografía y Geodesia		
Siboney	Cuba	23.1	-82.4667		Medium	Planned	Of.Nacional Hidrografía y Geodesia		
Maisí	Cuba	20.24811	-74.1433		Medium	Planned	Of.Nacional Hidrografía y Geodesia		
Casilda	Cuba	21.725	-80.3166		Medium	Planned	Of.Nacional Hidrografía y Geodesia		
Roseau/MACC project	Dominica	15.3	-61.3833	2008	High*	Existing		In request	
Punta Cana	Dominican Republic	18.5	-68.3		High	Existing	Fundacion Punta Cana		
Puerto Caucedo	Dominican Republic	18.4	-69.6	2008	High	Existing RTX	ONAMET/PRSN	3341059E	
Bahía de Samaná	Dominican Republic	19.2	-69.219	1999	High	Planned	INDRHI		
Bayahibe	Dominican Republic	18.36404	-68.8403	1999	High	Planned	INDRHI		
Bahía de Luperón	Dominican Republic	18.41194	-68.9666	1999	Medium	Planned	INDRHI		

Playa Diamante en Cabrera	Dominican Republic	19.6466	-69.9017	1999	Medium	Planned	INDRHI		
Puerto de Santo Domingo	Dominican Republic	18.4579	-69.9134	1999	Medium	Planned	INDRHI		
Barahona	Dominican Republic	18.21079	-71.0886	1999	Medium	Planned	INDRHI		
The Sisters Island,	Grenada	12.3	-61.7		Medium	Planned	Seismic Research Unit		
Sauteurs	Grenada	12.1	-61.75		High*	Planned	Seismic Research Unit		
Prickley Bay/MACC project	Grenada	12	-61.75	2008	Medium	Existing		In request	
Point a Pitre Harbour	Guadeloupe	16.2244	-61.5314		Medium	Existing	SHOM		
Grande Anse Harbour, Désirade Island	Guadeloupe	16.3028	-61.0734		Medium	Planned	IPGP		
Harbour Deshaies	Guadeloupe	16.3064	-61.7963		Medium	Planned	IPGP		
To be relocated/MACC project	Guyana	6.766667	-58.1667	2008	High	Existing		In request	
Honduras	Honduras	15.98722	-85.5916		High*	Gap			
Port Royal	Jamaica	17.9258	-76.8458	1953	High*	Planned	Meteorological Service		
				2008		Existing	MACC project	In request	
Discovery Bay, Jamaica	Jamaica	18.4666	-77.4167	1998	Medium	Planned	Meteorological Service		
Fort de France Harbour	Martinique	14.6015	-61.0632		High	Existing	SHOM		
Le Precheur Harbour	Martinique	14.8075	-61.2264		Medium	Existing	local authorities		
Montserrat	Montserrat	16.742	-62.19		High	Gap			
Curaçao	Netherlands Antilles	12.0997	-68.93	1981	Medium	Existing	Port Authorities		
Blue Fields	Nicaragua	11.891	-83.857		Medium	Gap			
Portobelo	Panama	9.55	-79.65	no knowledge	High	Gap	recommended by IOC-ICG-CEWS		
Mayagüez	Puerto Rico	18.2176	-67.1589	10/03/2007	High	Existing RTX	Puerto Rico Seismic Network	336633DE	
Aguadilla	Puerto Rico	18.4567	-67.1633	19/06/2006	High	Existing RTX	NOS	335E47798	
Mona Island	Puerto Rico	18.09	-67.3833	18/09/2006	High	Existing RTX	NOS	3365E288	
Arecibo	Puerto Rico	18.4669	-66.7024	08/03/200	Medium	Existing	Puerto Rico Seismic	3366454E	

				7		RTX	Network		
Fajardo, PR	Puerto Rico	18.3336	-65.6311	14/03/2007	Medium	Existing RTX	Puerto Rico Seismic Network	3366C35A	
Peñuelas	Puerto Rico	17.9667	-66.7618	27/02/2008	Medium	Existing RTX	Puerto Rico Seismic Network	3366A6BC	
Isabel II, Vieques	Puerto Rico	18.15	-65.4438	25/09/2007	Medium	Existing RTX	Puerto Rico Seismic Network	3366D02C	
Yabucoa	Puerto Rico	18.0551	-65.833	21/12/2007	Medium	Existing RTX	Puerto Rico Seismic Network	3366B5CA	
San Juan	Puerto Rico	18.4583	-66.115	25/03/1989	Medium	Existing RTX	NOS	335CA19E	X
La Esperanza, Vieques	Puerto Rico	18.0933	-65.47	12/08/2005	Medium	Existing RTX	NOS	335CC478	
Magueyes Island	Puerto Rico	17.97	-67.045	25/03/1989	Medium	Existing RTX	NOS	3364E042	X
Culebra Island	Puerto Rico	18.3	-65.3017	05/08/2005	Medium	Existing RTX	NOS	335CB2E8	
Baseterre/MACC project	St. Kitts	17.28856	-62.7226	2009	Medium	Planned		In request	
Castries/MACC project	St. Lucia	14.1666	-61	2008	Medium	Existing		In request	
Kingstown/MACC project	St. Vincent	13.1166	-61.1833	2008	Medium	Existing		In request	
Port Of Spain, Trinidad	Trinidad and Tobago	10.65	-61.5167	1982	Medium	Planned	Trinidad and Tobago Hydrographic Unit		
Charlottesville, Tobago	Trinidad and Tobago	11.31574	-60.5515	1998	Medium	Planned	CPACC?		
Point Fortin, Trinidad	Trinidad and Tobago	10.1833	-61.7	1982	Medium	Planned	Trinidad and Tobago Hydrographic Unit		
Scarborough, Tobago	Trinidad and Tobago	11.1667	-60.7333	1982	Medium	Planned	Trinidad and Tobago Hydrographic Unit		
Point Galeota, Trinidad	Trinidad and Tobago	10.12667	-60.9767	1998	Medium	Planned	CPACC?		
Lameshur Bay, St John	USVI	18.3167	-64.7233	02/08/2006	Medium	Existing RTX	NOS	335D10EA	
Lime Tree Bay, St Croix	USVI	17.6833	-64.7533	01/03/1991	Medium	Existing RTX	NOS	3364B03E	X
Charlotte Amalie, St Thomas	USVI	18.335	-64.92	23/02/1991	Medium	Existing RTX	NOS	3364A348	X
Christiansted Harbor, St Croix	USVI	17.75	-64.705	08/02/2006	Medium	Existing RTX	NOS	3365B2C4	

Punta Arenas, Margarita Island	Venezuela	10.97	-64.4		High	Gap			
Aves Island	Venezuela	15.7	-63.6		High*	Gap			

* defined as high due to its strategic location near an active volcano that has been considered to have the potential to generate tsunamis and strategic points for tsunami forecasting, including islands within the Caribbean Sea, as opposed to high priority stations defined by Henson et al (2006).

Appendix 2

Sea Level Station Operators in the Caribbean

Most of this information was gathered in the IOC-GLOSS-PRSN Caribbean Training Course for Operators of Sea Level Stations was hosted by the Puerto Rico Seismic Network in Mayaguez, Puerto Rico, June 2008. The name of the participant is in parenthesis.

USA NOAA NOS (Thomas Landon and Allison Allen)
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 station using VSAT for communications. It has procedures to process and analyze sea level data from tide gauges and DARTs.

PUERTO RICO (Christa von Hillebrandt, Javier Santiago, Victor Huerfano)
The Puerto Rico Seismic Network provides earthquake and tsunami information and warning for Puerto Rico and the Virgin Islands. It operates a network of 6 sea level stations in Puerto Rico and one in the Dominican Republic which is jointly operated with ONAMET. 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 TideView (WCATWC) are used to display the data. It also operates 24 seismic stations in the northeastern Caribbean and monitors in real time an additional 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. Funding is provided mainly by the UPRM, Government of Puerto Rico and NOAA. To complement the monitoring task, hazard and risk studies are conducted, as well as an education, preparedness and awareness program.

COSTA RICA – (Fernando Ureña)
Red Observación Nivel del Mar de América Central (RONMAC) was established in 2000 with funding from NOAA after Hurricane Mitch. Initially it covered several countries in Central America. Currently it is only operational in 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 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 in Grenada, but it was destroyed by wave action. SRC was to deploy 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 issues, 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 were to have installed by 2008. These will be integrated into the current CPAC project and archived at CIMH in Barbados.

BARBADOS Coastal Zone Management Unit (Ian Timothy)
Lack of local management and archival in Barbados has led to the unsustainability of the stations. 5 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 installed 2 stations and 2 others were planned March 2009. These stations are Deshaies, Guadeloupe, La Desirade, Guadeloupe, Le Prêcheur, Martinique,

Fort de France, Martinique. Each station is to have a radar and air pressure sensors. They requested a 5 minute slot for GOES transmission for each station.

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 – 1971. There have been two stations at Discovery Bay, none are functional.

BRITISH VIRGIN ISLANDS (Nigel Caines)
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 was installed in Road Town, it is transmitting over GOES. As soon as format of the data can be decoded they will be integrated into the Caribe EWS.

DOMINICAN REPUBLIC (National Hydraulic Resources Institute) (Irving Baez Morrillo)
INDRHI received funding to purchase 6 tide gauges. 4 gauges have been installed and, one was vandalized. The other three have onsite recording. Installation is pending for Santo Domingo and Punta Cana. One of the sea level visualization systems of the PRSN/DR project will be set up at INDRHI.

NATIONAL OFFICE OF METEREOLOGY OF THE DOMINICAN REPUBLIC (ONAMET) (Claudio Martinez)
ONAMET is the focal point of the Dominican Republic for the Caribe EWS. With the PRSN, and thanks to finding provided by the Government of the USA, it operates one Tsunami Ready tide gauge in Puerto Caucedo, Dominican Republic, along the southern coast. The data is transmitted in five minute slots over GOES and has been integrated into the Caribe EWS. There is a GOES receiver at ONAMET, but it is not operational. As part of the PRSN/DR tide gauge project, three sea level visualization systems will be set up at ONAMET, INDRHI and ISU.

CARIBBEAN COMMUNITY CLIMATE CHANGE CENTRE (CCCCC)
(Marvin Forde, CIMH, Barbados and Belen Martin Miguez, UNESCO**)**
18 sea level stations were installed throughout the Caribbean during the late 1990's as part of the Caribbean Planning for Adaptation to Climate Change (CPACC). Only 2 stations were reported

as operational up to 2005, but not transmitting. In 2004 The Caribbean Community Climate Change Centre (CCCCC) was designated by the governments of the Caribbean Community (CARICOM) to coordinate the Caribbean region's response to climate change. The Center Officially opened in August 2005. The website of the CCCCC is www.**caribbeanclimate**.bz. It is the official repository and clearing house for regional climate change data, providing climate change-related policy advice and guidelines to the CARICOM Member States through the CARICOM Secretariat. In this role, the Centre is recognized by the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Environment Programme (UNEP), and other international agencies as the focal point for climate change issues in the Caribbean. In 2006 the World Bank provided funding to CCCCC to upgrade/reinstall 12 of the original 18 stations. The Caribbean Institute of Meteorology and Hydrology (CIMH) was charged with providing the technical support for the station installation and maintenance in the Eastern Caribbean. In addition, a Regional Center of CCCCC is to be located at CIMH. As of 2009 CIMH had upgraded/installed the sea level stations in Guyana, Grenada, St. Lucia, St. Vincent, Barbados, St. Kitts, Dominica and Antigua. The other stations to be installed are to be located in Jamaica, Belize, the Bahamas and Trinidad and Tobago, the status of these four stations is unclear. As of April, 2009 none of these stations were transmitting over GOES according to CIMH.

Appendix 3.

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.