Intergovernmental Oceanographic Commission
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78

Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacents Regions (CARIBE-EWS)

Implementation Plan 2013–2017

UNESCO

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Executive summary

This current version of the Implementation Plan (ImpPlan) 2013–2017 updates on the status of the system, specifications of the requirements for designing and establishing the system for Tsunami and Other Coastal Hazards Warning System in the Caribbean and Adjacent Regions (CARIBE-EWS). It incorporates the work and views of the Intergovernmental Coordination Group (ICG) and of the sessional and inter-sessional Working Groups (WGs), namely of the WG 1 (Monitoring and Detection Systems, Warning Guidance), of the WG 2 (Hazard Assessment), of the WG 3 (Warning Dissemination and Communication), and of the WG 4 (Preparedness, Readiness and Resilience). The structure of the ImPlan is based on the participation of each WG in the development of the Early Warning System (EWS).

The 2008–2011 ImPlan proposed two phases of implementation. The Initial Phase involved the real-time seismic and sea level data exchange between existing Regional Seismic Networks (RSN) followed by the establishment of one or more Caribbean Tsunami Information Center (CTIC) and one or several regional tsunami warning centres (RTWC). The Second Phase CARIBE-EWS (Fully-fledged CARIBE-EWS) was to focus on the full development of the Early Warning System, which would cover both distant and local earthquake generated tsunamis and, as science permits, tsunamis generated by volcanic activity or by landslides, in cooperation with regional networks with this area of expertise. Currently, the first phase can be considered to almost have been met. The new ImPlan will thus focus on the second phase including: (1) Vulnerability, (2) Hazard Assessment, (3) Monitoring and Detection Systems, (4) Tsunami Services, and (5) Public Awareness, Education and Resilience.

It is to be noted that the implementation of the CARIBE-EWS is a complex process involving the Member States through their agencies and institutions as well as international organizations and local communities. In addition to the ICG Working Groups, the tasks are also to be completed thru task teams. This complexity implies that changes and on-the-way corrections are to be taken into account for this Implementation Plan in the course of the realization of the system, since implementation priorities, requirements or details may have to be adapted to new circumstances. Hence, the Implementation Plan will be at the same time a reference document, providing guidelines; and a dynamic document, reflecting the current status of the implementation of the Tsunami Warning System (TWS) at a given time. Updated versions of the Implementation Plan will be maintained at the Intergovernmental Oceanographic Commission (IOC) website and distributed at ICG/CARIBE-EWS sessions.

1. INTRODUCTION

The Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS) is a subsidiary body of the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). It was established in 2005, and is currently comprised of 32 Member States, 16 Territories in the Caribbean and Adjacent Regions and 3 Observer Member States (ANNEX **I**). Twenty-nine Members States have have officially designated Tsunami National Contacts (TNCs) and/or Tsunami Warning Focal Points (TWFPs), while in addition 9 of the Territories also have designated TWFPs. The ICG/CARIBE-EWS coordinates regional tsunami warning and mitigation activities, including the issuance of timely and understandable tsunami bulletins in the Caribbean. Comprehensive tsunami mitigation programmes require complementary and sustained activities in tsunami hazard risk assessment, vulnerability assessments, public awareness and education and emergency response, and preparedness. Stakeholder involvement and coordination is essential, and community-based, people-centered mitigation activities will help to build tsunami resiliency.

The current version of the Implementation Plan (ImpPlan) 2013–2017 contains the specifications of the requirements for further strengthening the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions.

It is to be noted that the implementation of the CARIBE-EWS is a complex process involving the Member States through their agencies and institutions as well as international organizations and local communities. Many tasks have and will continue to be accomplished thru Working Groups (WGs) and Task Teams (TTs). This complexity implies that changes and on-the-way corrections are to be taken into account for this Implementation Plan in the course of the realization of the system, since implementation priorities, requirements or details may have to be adapted to new circumstances. Hence, the Implementation Plan will be at the same time a reference document, providing guidelines; and a dynamic document, reflecting the current status of the TWS implementation at a given time. Updated versions of the Implementation Plan will be maintained at the Intergovernmental Oceanographic Commission (IOC) website and distributed at ICG/CARIBE-EWS sessions.

This ImPlan incorporates the work and views of the ICG and of the sessional and inter-sessional Working Groups, namely of the WG 1 (Monitoring and Detection Systems, Warning Guidance), WG 2 (Hazard Assessment), WG 3 (Warning Dissemination and Communication), and WG 4 (Preparedness, Readiness and Resilience).

The ICG/CARIBE-EWS strongly recommends that Member States to strengthen their tsunami warning capabilities, develop response protocols, define their level of tsunami threat, identify their vulnerability and engage in public awareness and education activities. The recently established Caribbean Tsunami Information Center (CTIC), the interim tsunami service providers, the Caribbean Tsunami Warning Program (CTWP), the proposed regional Tsunami Warning Centre, the UNESCO/IOC Tsunami Programme, and other regional and international emergency management and disaster coordination agencies are valuable resources for an end-to-end tsunami warning system.

2. STATUS

Significant progress has been made over the course of the first nine years of the CARIBE-EWS. Earthquake and tsunami observational and monitoring systems have progressed, the Pacific Tsunami Warning Center (PTWC) and the West Coast and Alaska Tsunami Warning Center (WCATWC) of the National Weather Service (NWS) of the United States of America are providing interim tsunami warning services, tsunami inundation modelling has been undertaken in many countries, tsunami warning reception and dissemination systems have been broadened and tested, tsunami protocols have been developed for many threatened areas and the public awareness and education on this hazard has also increased. With the establishment of the National Oceanic and Atmospheric Administration (NOAA) of NWS of the Caribbean Tsunami Warning Program in Puerto Rico, and the Caribbean Tsunami Information Center in Barbados, more dedicated resources are available to continue to advance and support the system.

Nevertheless, additional actions and measures are required to support the dissemination of warnings at the same standard as occurs in the remainder of the globe, where regional tsunami warning centres in the region have been established. Recommendations for improved tsunami disaster mitigation and warning include: real-time transmission of sea level data, improved tsunami inundation models, detailed near-coastal bathymetry, public awareness and education to create tsunami resilient coastal communities.

While significant progress has been made to improve earthquake and tsunami monitoring globally since the great 2004 earthquake and tsunami offshore of Sumatra, tsunamigenic events in the Atlantic and Caribbean are rare and not well understood. Numerous studies suggest that significant hazard exists in a relatively unprepared and unaware region. Tsunami potential for the Caribbean region should be studied in more detail such that additional locations for potential future tsunami sources can be identified, and maximum run-up heights in the region quantified accurately. Efforts to mitigate the associated hazard should include, at the least, education and public awareness to create resilient communities, and the support for international tsunami warning systems to focus efforts on the Caribbean and Atlantic basins.

The first implementation plan of the CARIBE-EWS consisted of a two-phase process with the objective of establishing the first core system of the TWS in the Caribbean region starting in 2008.

Initial Phase CARIBE-EWS (Initial CARIBE-EWS)

Some of the specific accomplishments of the Initial Phase were:

- Over the 2006–2013, the initial phase strengthened the real-time seismic data exchange between existing Regional Seismic Networks (RSN), the Tsunami Warning Centres, and the establishment of a real-time sea level data network. Currently 84% of the seismic station proposed in the Implementation Plan are exchanging data in real time. 100% (7/7) of the proposed DART stations are installed and 47% (50/107) of coastal sea level gauges are sharing data. An open access and continuous real time GPS network is also being installed.
- In January 2010, in Puerto Rico, NOAA established the position of Caribbean Tsunami warning program manager.
- The CTIC was established in Barbados through a Memorandum of Understanding between UNESCO/IOC and the Government of Barbados. Funding was secured for the establishment and the first 4 years of operation.
- TWFP and TNC were identified in 30 of the 32 Member States and in 9 of the 16 Territories.
- The Pacific Tsunami Warning Center of US NWS has provided interim Tsunami Watch services.
- Two Caribe Wave regional tsunami exercises (Exercise Caribe Wave 11.A Caribbean Tsunami Warning Exercise [IOC/2010/TS/93 rev.] and Exercise Caribe Wave/Lantex 13. A Caribbean Tsunami Warning Exercise [IOC/2012/TS/101 Vol.1])

have been conducted to test and evaluate communications between the Tsunami Warning Centres and the Tsunami Warning Focal Points and the dissemination and response systems in place.

- Many Member States have established Standard Operation Procedures (SOPs) for tsunamis.
- Public awareness and educational materials have been prepared, adapted and/or distributed throughout the region.
- The Caribbean Disaster Emergency Management Agency (CDEMA) developed the Tsunami Smart project with a wide variety of English language materials.
- Many Member States and their Territories developed and conducted local tsunami readiness and preparedness programmes, including the TsunamiReady program which was adapted by the CARIBE-EWS as a Pilot Project, and the Tsunami Smart program, which was developed for use by the island states of the Caribbean Community (CARICOM).

Second Phase CARIBE-EWS (Fully-fledged CARIBE-EWS)

The second Phase CARIBE-EWS (Fully-fledged CARIBE-EWS) focuses on the full development of the Early Warning System, which would cover both distant and local earthquake generated tsunamis and, as science permits, tsunamis generated by volcanic activity or by landslides. It also recognizes the ongoing need to strengthen other components of the system. The main components of this second phase are: (1) Vulnerability, (2) Hazard Assessment, (3) Monitoring and Detection Systems, (4) Tsunami Services and (5) Public Awareness, Education and Resilience.

The following chapters cover the Second Phase CARIBE-EWS implementation details as well as some remaining issues from the First Phase CARIBE-EWS implementation.

3. GOVERNANCE

The document *Intergovernmental Coordination Group For The Tsunami And Other Coastal Hazards Warning System For The Caribbean And Adjacent Regions (ICG/CARIBE-EWS) Organizational Structure And Governance* describes the various components of the ICG and how they work together to enable an effective international warning system. The Intergovernmental Coordination Group (ICG), which is an subsidiary body of the Intergovernmental Oceanographic Commission (IOC) that reports to the IOC Assembly or Executive Council. The ICG/CARIBE-EWS was established by IOC Resolution XXIII-14 in 2005 as a regional international body, and has met every year since 2006. The ICG/CARIBE-EWS Officers are elected by the Member States and include a Chairperson, 3 Vice-Chairpersons along with the elected Officers (Chair and Vice-Chairs) of the Working Group. CARIBE-EWS work is enabled through Working Groups (WG). Intra-sessional (or sessional) WGs work during an ICG and report back to the ICG in which they were established. Inter-sessional WGs work between ICGs and report at the next ICG. Currently the CARIBE-EWS has 4 inter-sessional Working Groups:

- WG 1: Monitoring and Detection Systems, Warning Guidance.
- WG 2: Hazard Assessment.
- WG 3: Warning Dissemination and Communication.
- WG 4: Preparedness, Readiness and Resilience.

It is recommended that the inter-sessional Working Group Structure be restructured and/or re-named as follows:

- WG 1: Monitoring and Detection Systems.
- WG 2: Hazard and Risk Assessment.
- WG 3: Tsunami Services (gathers the Warning Guidance of previous WG 1 and Warning Dissemination and Communication of previous WG 3).
- WG 4: Public Awareness, Education and Resilience.

In addition, each Member State is represented by a Tsunami National Contact that serves as the ICG contact and the country's coordinator of its international tsunami warning and mitigation activities. The Tsunami Warning Focal Point (TWFP) designated by the Member State is the 7x24 contact person, or other official point of contact for rapidly receiving and issuing tsunami event information (such as warnings).

The Tsunami Unit (TSU) of the IOC presently coordinates the 4 tsunami warning and mitigation systems and works to identify the commonalities in terms of specifications, guidelines, standards, procedures and processes including developing synergies with existing technical groups dealing with related matters. The ICG/CARIBE-EWS Secretary provides, upon request by the IOC governing bodies, secretarial support for the ICG. The CARIBE-EWS Technical Secretary (CTS) coordinates and facilitates the activities of the ICG, interacting directly with Member States and regional organizations.

The Caribbean Tsunami Information Center (CTIC) is charged to improve all aspects of tsunami warning and mitigation including hazard assessment, warning preparedness and research. As of 2011, it is hosted by the Government of Barbados.

The Pacific Tsunami Warning Center (PTWC) serves as the interim international operational tsunami warning headquarters for the CARIBE-EWS. The Sub-regional centre in Alaska (WCATWC), USA, works closely with the PTWC and currently provides warning services to Puerto Rico and the US Virgin Islands. The centres issue timely tsunami alerts to designated national authorities who then take action to protect their populations. The USA Caribbean Tsunami Warning Program was established in Mayagüez, Puerto Rico, in 2010 as part of phased approach of the US Government towards a Caribbean Tsunami Warning Center.

4. CAPACITY ISSUES

During the first phase of the ImpPlan, efforts were made to develop capacity in key areas necessary for the ICG’s objectives while, at the same time, bringing together groups of persons who were non-traditional partners in hazard management. Meteorologists, marine scientists and disaster managers began to work together to build an end-to-end tsunami warning system that would be resilient, have redundancy, and engender trust in the minds of the public. It was also clear that hazard assessment was an area of weakness for the Caribbean in general, and training workshops were planned and implemented to address this capacity issue.

One area of focus for this new phase of the ImpPlan is that of vulnerability assessment, where it is expected that the ICG will build on previous hazard assessment work to assess the real economic and social vulnerabilities of Member States of the wider Caribbean region. A number of vulnerability assessment tools exist and must be evaluated for utility by the ICG. However, in order to accomplish this goal, there needs to be active engagement with the social science community, a group of experts with whom the ICG has had little contact to date.

It is also recommended that, given the multi-disciplinary nature of the work of the ICG, Member States and the Tsunami Unit (TSU) of IOC constantly evaluate the necessity to develop or engage experts from other fields, to continually improve the efficacy of the CARIBE-EWS.

5. ACTION PLANS

The current version of the Implementation Plan (ImpPlan) is described through a series of actions which are needed to develop and maintain different components of an end-to-end tsunami warning and mitigation system for the Caribbean region. Action plans represent a consolidation of planned, ongoing, and proposed actions based on working group outputs of the ICG/CARIBE-EWS, as well as work plans of ongoing national and international programs in the region. These action plans are intended to provide a framework to periodically update and monitor the system status at a regional level.

5.1 VULNERABILITY

5.1.1 Introduction

Since the devastating earthquake that struck Haiti on 12 January 2010, awareness of population and infrastructure vulnerability has increased in the Caribbean region. However, a significant tsunami event has not occurred in ocean basins of the Atlantic and Caribbean within the lifetime of most residents and structures. For this reason, there is a general lack of awareness and understanding of the destruction that such an event could cause. The vulnerable economies of Small Island Developing States (SIDS) in the Caribbean are based on coastal tourism, requiring the installation of expensive infrastructure within or near tsunami inundation zones. In addition, large cruise ships within harbours are also at risk, along with coastal pleasure craft and yachts within marinas.

Despite inherent uncertainty, it is clear from numerous studies that the subduction zones of the Puerto Rico Trench and the Lesser Antilles are capable of producing a large and damaging earthquake (Manaker et al., 2008, Mann et al., 2005; Mann et al., 2002, McCann et al., 1984). In addition, the Caribbean region is at risk from a tsunami generated by other mechanisms such undersea landslides and volcanic activity. This is particularly concerning given the vulnerability of communities and infrastructure in a region that has experienced significant population increase in the past 50 years (Hyman, 2005) and receives over 35 million visitors every year (Proenza and Maul, 2010). The growth of large coastal cities and shipping harbours near this seismically active region often includes the construction of potentially unsafe buildings and infrastructure due to an insufficient knowledge of seismic hazard combined with economic constraints. Minimization of the loss of life, infrastructure damage and economic impact due to earthquakes depends on accurate and reliable estimate of seismic and tsunami hazard in the region.

Such a “short fuse” tsunami would provide very little preparation time for the local island communities and pose very high risk to the estimated 500,000 daily beach visitors (Proenza and Maul, 2010). In this case, loss of life due to population vulnerability may be particularly high given that the majority of these visitors are drawn to the warm waters of the Caribbean from inland areas of the United States and Europe and may not be aware of the threats posed by tsunamis. In addition, as witnessed in the recent Japan tsunami of 11 March 2011, even well prepared communities with adequate warning systems are not necessarily able to react in time to minimize extensive loss of life and infrastructure damage. For this reason, critical components to tsunami hazard mitigation are well-defined procedures and routes for evacuation, as well as long-term education.

5.1.2 Action Plan

Actions	Responsibility	Timeline	Estimated Costs
Engage the social science community within Member States and Caribbean universities, as an important prerequisite to addressing vulnerability issues in the medium-term.	Member States, IOC Tsunami Unit, CTIC.	2013–2014	0
Define the key vulnerability parameters for CARIBE-EWS, e.g.: Tourism visits, beach visits, cruise ships.	Task Team and other key Economic and Social Stakeholders.	2014	0
Organize a training workshop on vulnerability assessment tools applicable to tsunamis.	IOC, CTIC, Member States.	2014–2015	$50,000

Table 1. Action Plan for Vulnerability Assessment

5.2 HAZARD ASSESSMENT

5.2.1 Introduction

Hazard and risk assessment for tsunamis and other coastal hazards is a key element of any TWS. These are mainly characterized on the basis of documentation of historical events and impacts, of the geological and geophysical knowledge of the sources and of their dynamics, of tsunami generation, propagation and inundation modelling, and of the exploration of an expected range of scenarios.

A key issue for establishing the tsunamigenic potential of an earthquake is the relationship between the earthquake source parameter (mainly epicentre, focal depth and size in terms of magnitude or seismic moment) and the expected tsunami size. This knowledge is crucial since it provides the basis to build the TWS decision matrix, namely the matrix, that is used in the TWS operations to evaluate the size of the potential tsunami and to respond with the appropriate action. Auxiliary data sets required for a proper analysis of hazard are the tectonic setting of the region, inclusive long-term and short-term deformation pattern of the plates, the distribution of the major active seismic faults and the historical seismicity in the coastal zones and offshore. Further data include updated bathymetry in the open sea and detailed bathymetry in the coastal belt, especially in the shallow-water zone with depth less than 100 metres up to the coastline, where tsunami interaction with sea bottom becomes quite complex and non-linear wave behaviour may prevail. In addition, topographic data at the coast in terms of digital terrain or elevation models are required. Finally, paleotsunami studies must be carried out since recent megathrust events in subduction zones have demonstrated the dangers in relying in the short-time interval for which seismicity and tsunami data are available (Morra et al., 2013). The 2011 Tohoku, Japan, event has shed doubt about the standard scaling laws between rupture area, fault slip, and magnitude, applicable to most thrust quakes (Okal, 2013), and recent research suggests that our region is capable of a Mw 9 event (Gutscher, 2013).

Despite inherent uncertainty, it is clear from numerous studies that the subduction zones of the Puerto Rico Trench and the Lesser Antilles are capable of producing a large and damaging tsunamigenic earthquake (Manaker et al., 2008, Mann et al., 2005; Mann et al., 2002, McCann et al., 1984). In addition, the Caribbean region is at risk from a tsunami generated by other mechanisms such as submarine landslides and volcanic activity. The tsunami hazards for coastlines in the Gulf of Mexico, Atlantic Ocean, and Caribbean Islands are unique in that practically all the known causes of tsunamis are present, including earthquakes, submarine landslides, and island volcanoes. For example, large submarine landslides pose significant tsunami hazard along with earthquakes.. The tilt caused massive slope failures, which appears to continue, as evidenced by large fissures in the seafloor. Volcanoes are other sources of tsunamis that can be caused either by volcano flank collapses or more locally by pyroclastic flows.

In addition to local earthquake and tsunami risk, an earthquake on the subduction zones of the Puerto Rico Trench and the Lesser Antilles pose a potential threat to the greater Atlantic basin through a transoceanic tsunami. The subduction zones of the Caribbean are the closest convergent plate boundaries to the eastern coasts of North and South America and the western coasts of Europe and Africa (Geist and Parsons, 2009). As evidenced by the Japan tsunami of 11 March 2011, a Pacific basin wide tsunami warning can significantly reduce loss of life, relative to the experience of the devastating Indonesia tsunami of 26 December 2004.

With several hundred million people now living in coastal areas surrounding the Caribbean, and with major earthquakes occurring on average every 50 years, it is not a question of whether a destructive tsunami will occur but when. While significant progress has been made to improve earthquake and tsunami monitoring and modelling globally since the great 2004 earthquake and tsunami offshore of Sumatra, tsunamigenic events in the Atlantic and Caribbean are rare and not well understood. Numerous studies suggest that significant hazard exists in a relatively unprepared and unaware region. Tsunami potential for the Caribbean region should be studied in more detail such that additional locations for potential future tsunami sources can be identified, and maximum runup heights in the region quantified accurately. Efforts to mitigate the associated hazard should include, at the least, education and outreach to create resilient communities, and the support for international tsunami warning systems to focus efforts on the Caribbean and Atlantic basins.

5.2.2 Action Plan

Action	Responsible	Timeline
Seek the funding and organize a second Workshop on Tsunami Modelling	WG 2 Chair and Co-Chair, UNESCO Tsunami Unit.	2014
Update and enlarge existing tsunami hazard maps building on the existing CDEMA and CEPREDENAC previous efforts	Member States, Multi-country, Multi-agency.	On-going
Develop a list of tsunami models for sub-aerial and submarine landslides that have been validated and benchmarked and can be used in the Caribbean.	WG 2	2013

Action	Responsible	Timeline
Work with IOC and other organizations to identify funding for tsunami inundation modelling for sub-aerial and submarine landslides.	WG 2 and UNESCO Tsunami Unit	On-going
Request validation of tsunami models using Tsunami Runup data in the historical NOAA/NGDC database.	Technical Secretary with NGDC support, through TNCs.	2015
Define the elements needed for a database on tsunami sources for the Caribbean that can be used for tsunami modelling.	WG 2	2013
Maintain database of existing tsunami inundation maps and tsunami modelling capability for CARIBE-EWS.	WG 2	Annual
Integrate Tsunami Warning System with existing and planned coastal hazard mitigation and preparedness systems.	TNCs	On-going

Table 2. Action Plan for Hazard Assessment

5.3 MONITORING AND DETECTION SYSTEMS

5.3.1 Introduction

An efficient and effective tsunami warning system requires seismic, sea level and other observational data that must be available and processed in an efficient, reliable and timely manner, real-time. As part of the CARIBE-EWS, the monitoring, detection, analysis, and broadcasting capabilities in the region need to be advanced so that the TWFPs (Tsunami Warning Focal Points) as well as the population can be timely alerted to potential tsunami threats and the corresponding actions can be taken to save lives. A Caribbean Tsunami Warning Center in the region is also needed to provide the fastest possible tsunami alerts for the timely response of the populations to avoid unnecessary evacuations which can have a significant impact on the economies of the region.

Every monitoring network should be :

- Dense enough to ensure performance detection criteria are met;
- Redundant enough to ensure performance criteria are met even in case of partial failure of the network;
- Available for scientific studies for better hazard assessment.

Up until 2013, a lot of stations have been installed in the region, enhancing the capacity of the existing CARIBE-EWS. There are still gaps existing that needs to be filled and it is still necessary to reinforce the networks in some regions and to enhance the overall data availability at the warning centres.

5.3.2 Seismic measurements

Numerous local, national and regional seismic networks are established in the region for monitoring earthquake activity. Data are also available from the adjoining regions, mainly from the global seismic networks. Real-time seismic data are also available to Tsunami Warning Centres recognised by UNESCO/IOC from the Preparatory Commission (PrepCom) for the Comprehensive-Test-Ban Treaty Organization (CTBTO).

An effective and reliable real-time seismic data exchange system must be put in place to detect and identify tsunamigenic earthquakes for tsunami warning and forecast. With this aim, minimum requirements for seismic station specifications serving tsunami monitoring purposes have been defined and performance standards set. An inventory of established or planned (funded) seismic stations that meet the minimum requirements has been elaborated (Figure 1). Following that, a subset of seismic stations to be part of the CARIBE-EWS has been selected as the core seismic network. The seismic network performance standards recommended by WG 1 to serve CARIBE-EWS earthquake monitoring require detection within 1 minute for all earthquakes in the region of magnitude 4.5 or greater. These standards will permit that earthquake source parameters can be determined in 1–2 minutes and the corresponding products for potentially tsunamigenic events can be distributed within 5 minutes while meeting accuracy criteria.

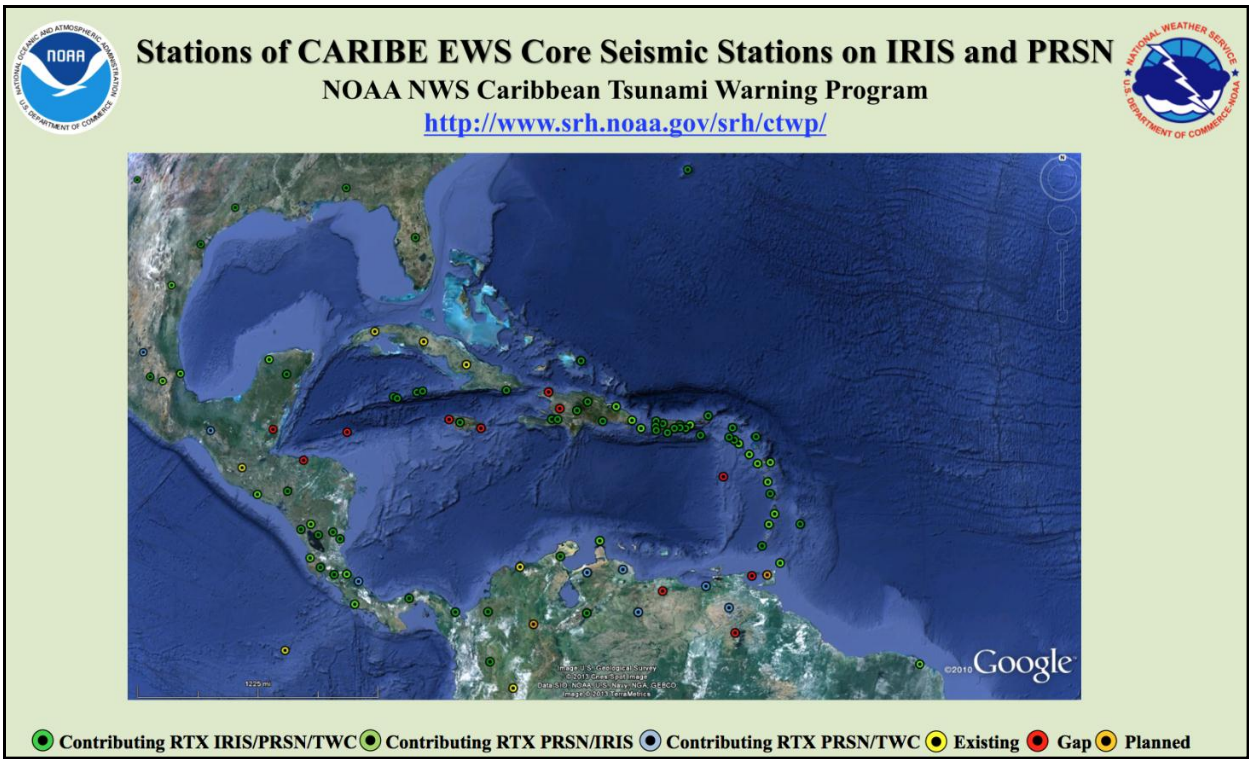

Figure 1. Seismic stations in the CARIBE-EWS region as of April, 2013.

The National Earthquake Information Center (NEIC) of the United States Geological Survey (USGS) has produced numerical models to determine the minimum magnitude threshold, detection time, and earthquake location error for the seismic network in the Caribbean region. This model was run on three network scenarios based on:

- the existing seismic stations available in real-time to the CTWP and PTWC in 2006 (Figure 2),

- the existing seismic stations available in real-time to the CTWP and PTWC in 2013 (Figure 3) and,
- the existing and planned real-time seismic stations (Figure 4).

As seen in Figure 2, in 2006 very few seismic stations in the area were available to the PTWC and consequently the seismic network performance standards, required by WG 1, were poorly met throughout the region. The exception was in the vicinity of Puerto Rico, where earthquake could be detected in less than one minute. Outside of the Puerto Rico region, earthquake detection time was on the order of many minutes.

As of April 2013, the 105 CORE existing real-time seismic stations available to the CTWP and PTWC nearly meet the performance standards established by WG 1 (Figure 3). Recent network additions (Nicaragua, Colombia, Mexico, Cayman Islands, Venezuela) have reduced detection threshold, time and location error throughout much of the Caribbean region and Central America. For example, Figure 3 shows that earthquakes in the Caribbean can be detected within 1 minute. Exceptions to this are northern South America and portions of Mexico.

Figure 4 shows that adding planned and other Caribbean stations to the Existing-RTX network, the network detection time is improved over the current existing real-time network (Figure 3) and meets performance standards established by WG 1, throughout the entire region. Further analysis is needed to determine the minimum number of seismic stations that need to be added to the monitoring network so that the performance standards can be met. Gaps were already identified in northern Colombia, Panama, Honduras, Guatemala, Yucatan Peninsula and Jamaïca/Haïti region. In addition, due to the limited distribution of island, ocean bottom seismometers (OBS) should be considered in order to fill gaps in the existing land-based seismic network. Nevertheless, if the presently available seismic stations that are operational in the region, including those of local and regional networks and CTBTO stations are used, the performance criteria could be met. Therefore the ICG/CARIBE-EWS encourages network operators that have stations currently operational to make them available in real-time.

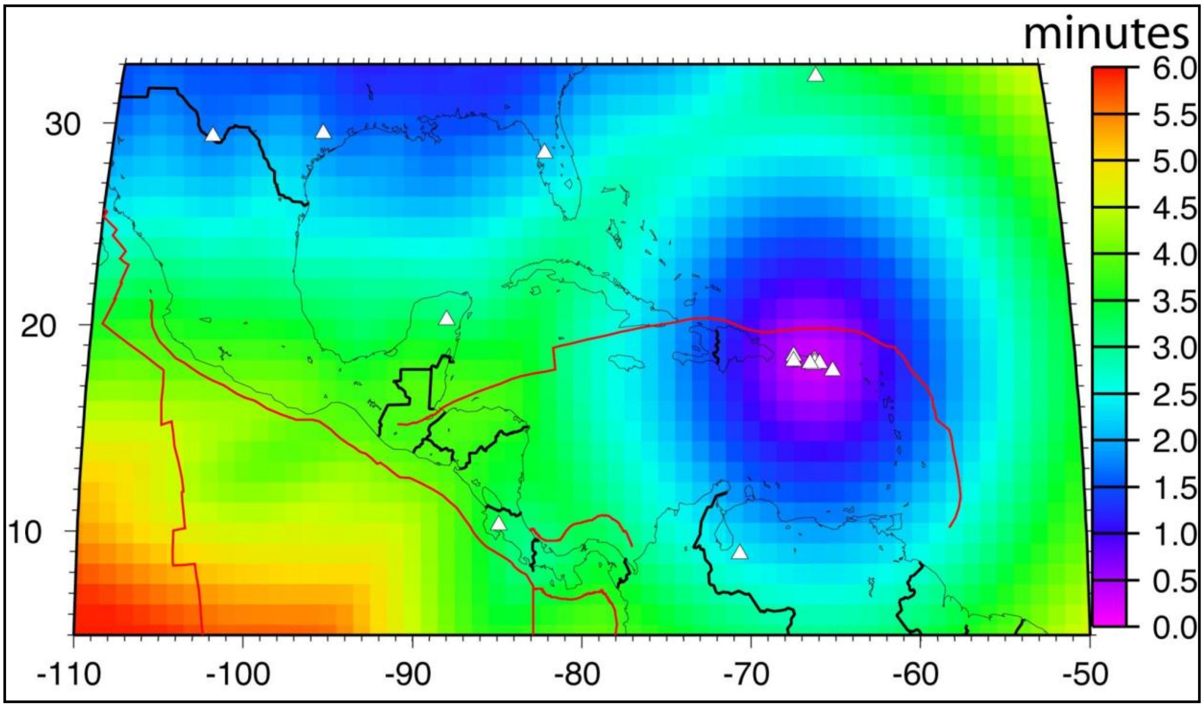

Figure 2. Modeled detection time using existing real-time seismic stations available to the CTWP and PTWC in 2006. Red lines represent trenches where earthquakes are likely to occur. Seismic network performance standards were poorly met throughout the region except in the vicinity of Puerto Rico, where an earthquake could be detected in less than one minute.

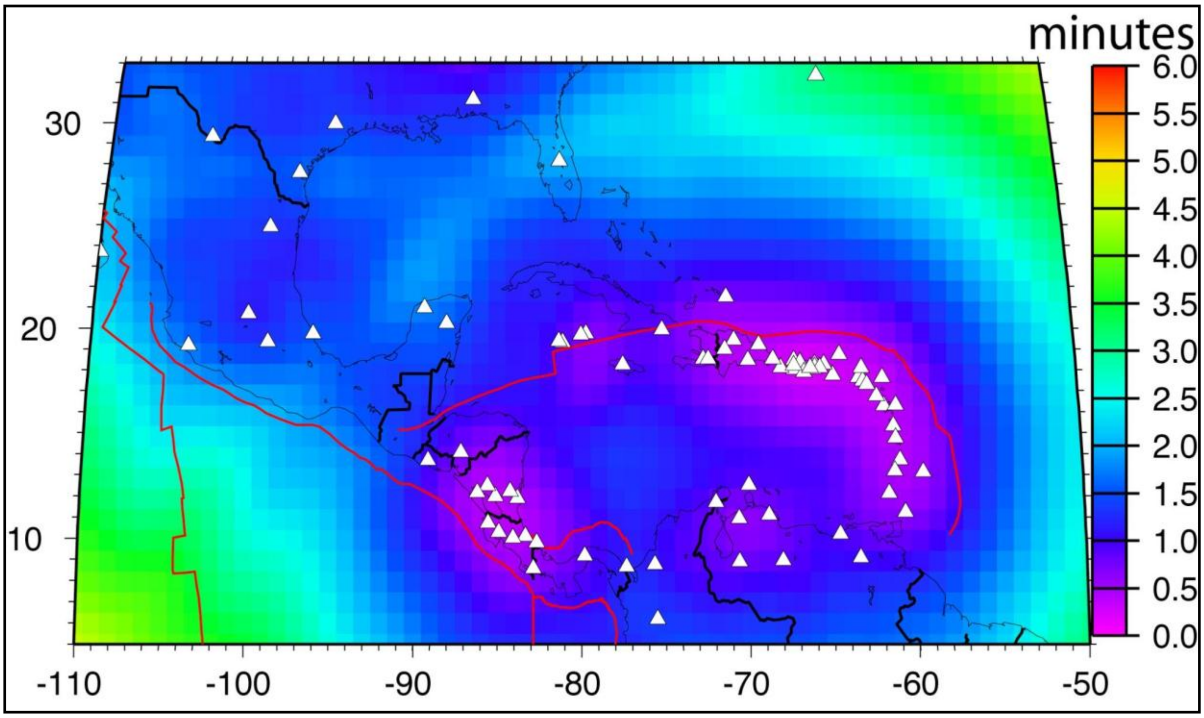

Figure 3. Modeled detection time using existing real-time seismic stations available to the CTWP and PTWC. As of April 2013. Red lines represent trenches where earthquakes are likely to occur. Seismic network performance standards are nearly met throughout the region where an earthquake could be detected in less than one minute. Weaknesses in earthquake detection time still exist in the north in the Gulf of Mexico and along the northern regions of South America where earthquake hazard is low.

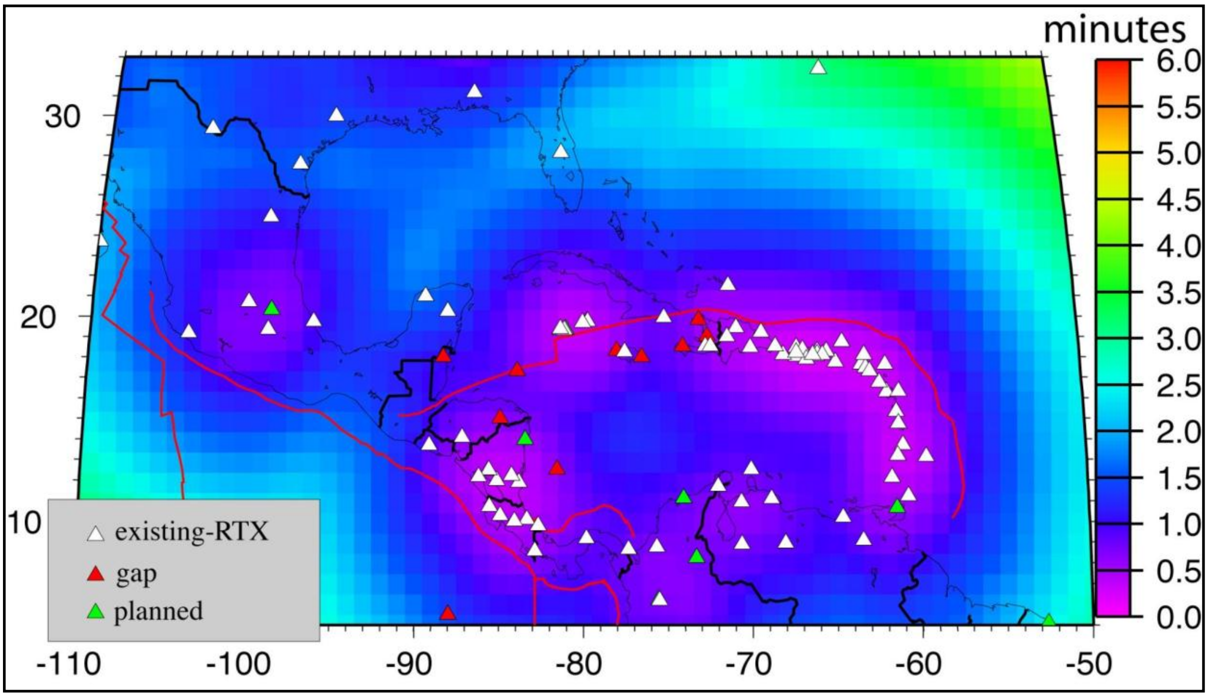

Figure 4. The map shows the regional P-wave detection time model for the complete CORE network. The “CORE” network is currently composed of existing seismic stations (white triangles) that currently contribute data in real-time to the CTWP, stations that do not yet exist but fill gaps in the network (red triangles) and planned stations (green triangles) that do not yet exist. Red lines represent trenches where earthquakes are likely to occur. Seismic network performance standards are nearly met throughout the region where an earthquake could be detected in less than one minute. Weaknesses in earthquake detection time with the existing real-time network (Figure 3) are improved in the north in the Gulf of Mexico and along the northern regions of South America.

5.3.2.1 Seismic network maintenance and sustainability

At this time, since the minimum performance standards are met throughout the region, focus should be brought on vulnerabilities and weaknesses in the system, in order to design a robust seismic network. Redundancy is critical in order to avoid data outages due to communication problems, vandalism, hurricane damage, aging hardware and other possible failure scenarios. This is especially true in the event of a destructive earthquake and/or tsunami when weaknesses in the system most likely cause points of failure, as the 2011 Tohoku earthquake has shown. Significant support should be provided to regional and national network operators to ensure the sustainability of the “CORE” seismic network through shared resources and maintenance.

A critical component of real-time seismic network operations is a reliable and robust communications system. It is suggested that the seismic data exchange is done using Earthworm and Seiscomp (seed link) systems, which are currently used worldwide, and in the region, and are freely and openly available through organizations such as the IRIS (Incorporated Research Institutions for Seismology) Data Management Center (DMC). Seismic networks that do not have real-time data exchange mechanisms will require training. On the other hand, significant investments may be required in some areas for upgrading data transmission and communication means. Internet will be the platform for seismic data exchange, while over the mid-term and long-term, additional technology, like VSAT (Very Small Aperture Terminals) and dedicated lines for seismic data exchange, should be explored in order to improve the robustness of the data links. The Puerto Rico Seismic Network (PRSN) is acting as a distribution hub for seismic data in the region. At least one additional hub should be identified to ensure redundant data transmission means for better seismic data availability. The sustainability of such a network must be ensured. A maintenance and training program to sustain seismic monitoring networks has to be developed and implemented.

5.3.3 Sea level measurements

Real-time data sea level networks are one of the essential components of tsunami warning centres. After the seismic information has been received and analyzed, certain seismic parameters are met establishing a potential tsunami threat; sea level and water pressure data allow to confirm the hazard and forecast its severity or to declare the threat is over. In the case that the tsunami is generated by a non seismic source, the sea level data will be the primary tool for the detection and evaluation of the threat. There are different types of sea level data that can be used to detect tsunami waves: data from coastal tsunami ready tide gauges, HF radar, Deep-ocean Assessment and Reporting of Tsunami (DART) Ocean buoys (See Figure 5) and coastal buoys.

As of April 2013, a big improvement on the number of available coastal sea level stations is to be noted. Over the past years, the network has grown from a handful of stations to almost 50 stations (Figure 6) sending data in real-time. The number of those coastal sea level stations in the Caribbean and Western Atlantic that meet Technical and Logistical and Administrative Requirements of the Regional Tsunami Warning Centre for the CARIBE-EWS in support of the Caribbean Tsunami Warning Center (Working Group I: Technical, logistical and administrative requirements of a Regional Tsunami Warning Centre for the Caribe EWS [ICG/CARIBE–EWS-IV/13]) is currently still growing. A core network of sea level stations based on the most likely sources that will generate regional and Caribbean wide tsunamis has been defined. The proposed stations and the current status of sea level station are presented in ANNEX I, and are displayed through the CARIBE-EWS of IOCARIBE (IOC Sub-Commission for the Caribbean and Adjacent Regions) interactive map available at http://www.srh.noaa.gov/srh/ctwp.

One of the requirements is that all sea level data should be made available through the Global Telecommunication System (GTS) for a broad and more robust data sharing. The US is making every effort to accommodate all the request for high rate slots (at least 6 minutes) on GOES (Geostationary Operational Environmental Satellite), from where it is easy to load into the GTS. It has established with the CARIBE-EWS a process for the submission and approval of requests for high rate slots. Alternatives to GOES Data Collection System (DCS) for robust high rate transmission and getting data into the GTS still need to be explored by the Intergovernmental Oceanographic Commission (IOC), the World Meteorological Organization (WMO), and the station operators. Alternate sharing method should also be explored for the Tsunami Warning Centre, and in order to decrease the data latency for very short fused events. Even in case GOES transmission is available, a second transmission media should be used for enhanced data availability.

Tools have been developed to view and analyse sea level data. Tools like those developed by NOAA (www.sealevelstations.org), by VLIZ/IOC Sea Level Monitoring Facility (http://www.sealevelstation.net), or by the PRSN DANIS tsunami tool kit (http://www.prsn.uprm.edu) are used to monitor and display the regional sea level data. Tsunami Tide Tool has been developed, maintained and distributed by PTWC and ITIC (International Tsunami Information Centre), and supported by the CTWP. It has been installed by data centres and station operators to analyse sea level data. Tide View of the West Coast and Alaska Tsunami Warning Center and commercial packages are viable another alternatives for sea level data acquisition, processing, distribution and analysis. The sustainability of the sea level stations needs to be ensured. A maintenance and training programme for the operators and the users of sea level monitoring networks has to be developed and implemented. The multipurpose applications is also very important for the sustainability of the stations and links with other partners in the sea level, climate and hydro met communities need to be explored.

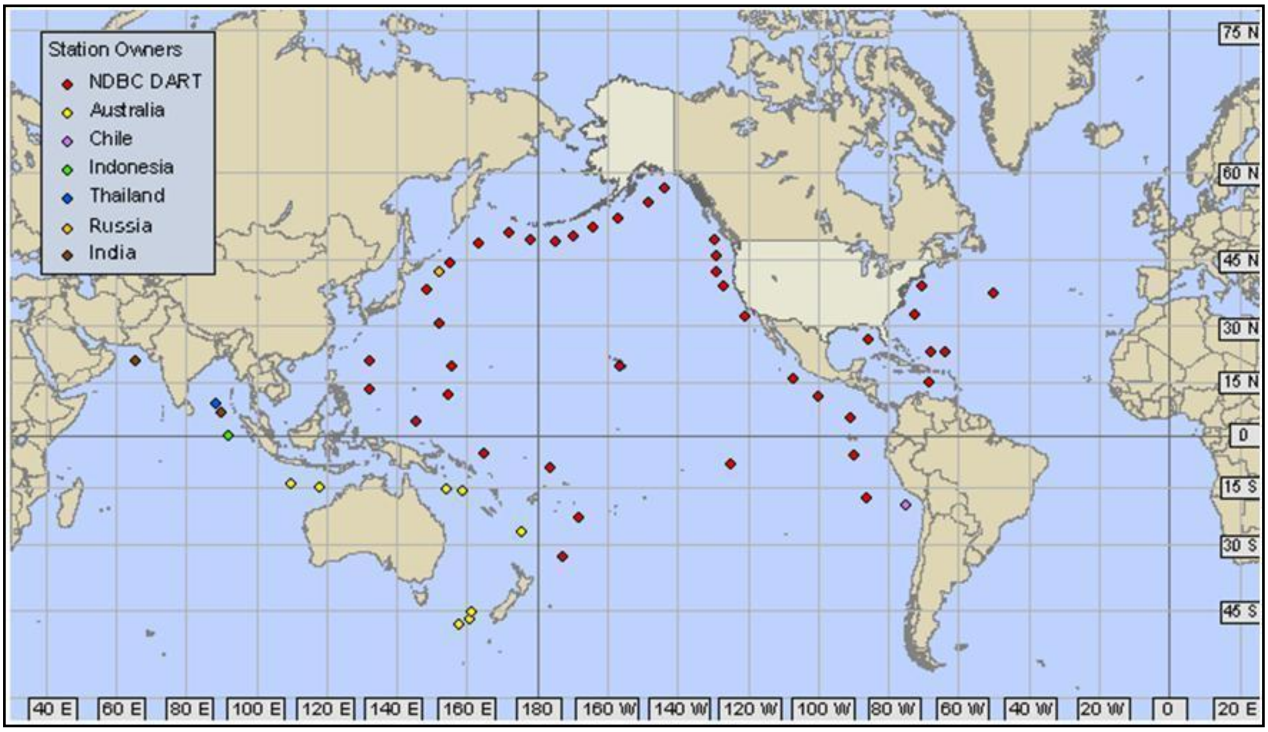

Figure 5. DART buoy locations
(from website: http://www.ndbc.noaa.gov/dart.shtml, March 2012)

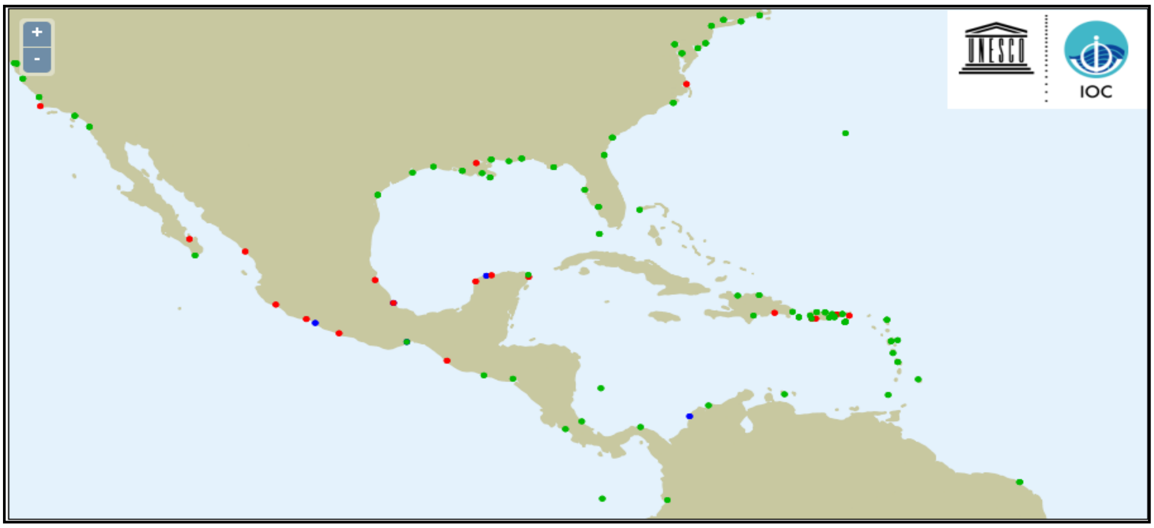

Figure 6. Caribbean Sea Level Monitoring Stations:
(updated March 2013; http://www.ioc-sealevelmonitoring.org/map.php)
Green colour means online, red means down, blue means data are available elsewhere.

Significant progress has been made to improve earthquake and tsunami monitoring capabilities in the region, however, more is needed to support the dissemination of warnings at the highest standards as occurs in other basins. Recommendations for improved tsunami disaster mitigation and warning include: high availability real-time transmission of seismic and sea level data, improved tsunami inundation models, detailed near-coastal bathymetry, education and outreach to create “tsunami ready” communities, and focusing of international tsunami warning systems on the ocean basins of the Caribbean and Atlantic.

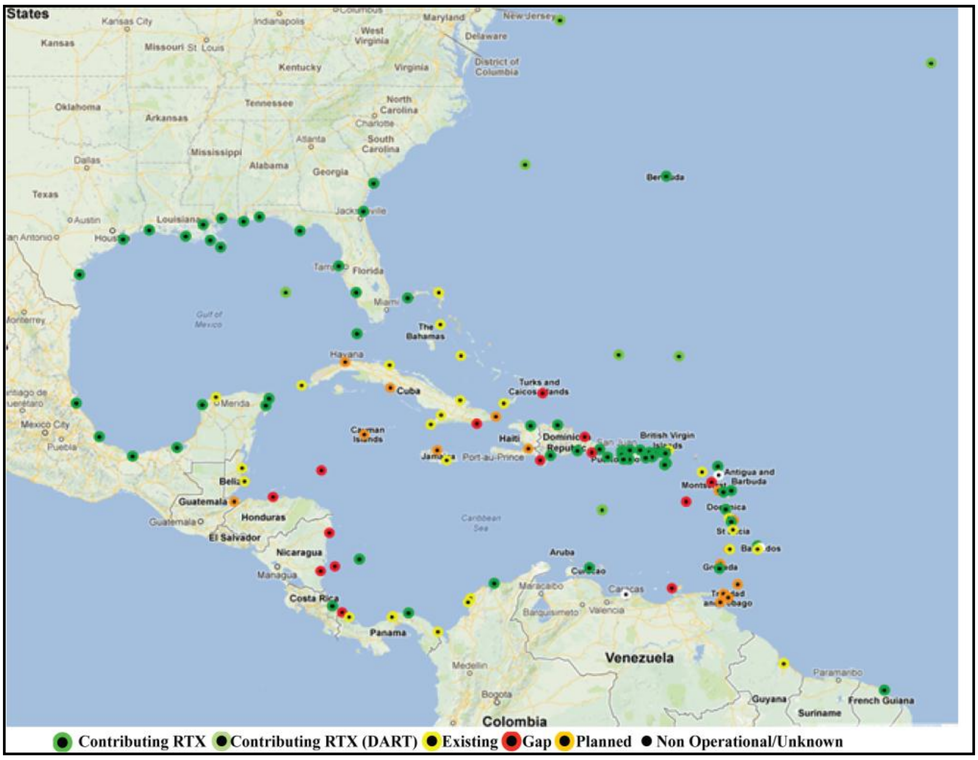

Figure 7. Caribbean Sea Level Monitoring Stations
(updated April 2013: http://www.srh.noaa.gov/srh/ctwp/)

5.3.4 Tectonic Deformation and remote sensing measurements

There is a clear evidence for rapid co-seismic height changes of the surrounding land during strong and tsunamigenic earthquakes. These elevation changes cause variations in the local sea level a few minutes after an earthquake occurs, which may mask or overlap any tsunami-related sea level change. There are many references that confirm that larger subduction zones like the Puerto Rico Trench and the Eastern Antilles, and extensional areas, like the Mona Canyon or the Anegada Passage, also experience large deformations previous to a mega-event. Therefore, high precision continuous GPS are fundamental part of a Tsunami Warning Centre. Typical high rate GPS data is sampled at 1 Hz and stored at the GPS site and distributed over TCP/IP (Transmission Control Protocol/Internet Protocol) data servers. In the case of a tsunami alert or a strong earthquake, GPS data, which can be transmitted to a Tsunami Warning Centre, could be used to refine tsunami forecasting models.

Currently, there are efforts to use GPS data to invert for the focal geometry and earthquake magnitude. For very strong earthquakes, it has been proved in the last years that GPS data could lead to an accurate magnitude estimation, which is critical for a good characterization of the expected tsunami amplitude, quicker than traditional seismic measurements inversion techniques. Other efforts using simultaneously tide and GPS data are to constrain the earthquake-affected sea level station; ideally the vertical displacement to the pre and post-earthquake situation is computed in real-time and the result is merged with the sea level data from the tide gauge station. The computed vertical displacement is used as an acceptance/rejection criterion for the sea level record of the particular tide gauge station in order to assist the decision process and avoid false tsunami detections. In cases of vertical displacements of a coastal region during an earthquake, the sea level in the GPS monitored region will slowly adapt to a new level. Because it is difficult to model how the sea level adapts for a certain vertical displacement, the information from a tide gauge must be rejected for displacements larger than 10 centimetres. In addition, the 1 Hz GPS data can be used to estimate, e.g. the temporal-spatial distribution of the slip during an earthquake that can reinforce tsunami generation models. It is strongly recommended to support this research topic.

Between 2010 and 2013, the Continuously Operating Caribbean GPS Observational Network (COCONet) project funded by the US National Science Foundation (2010–2012) is installing 50 GPS permanent stations (Figure 8) and integrating an additional existing 50 GPS stations to reinforce the tectonic deformation studies, the tsunami warning centre (UNAVCO COCOnet network) and meteorological applications. The CARIBE-EWS encourages the participation of the Member States and the tsunami warning centres in this project. There are other remote sensing efforts to detect incoming tsunamis like direct Satellite observations, and optic and electric properties of the ionosphere.

Figure 8. Distribution of COCONet GPS stations (2012)

5.3.5 Action Plan

Actions	Responsibility	Timeline	Estimated Costs
Establish a Task Team to address the full implementation of the observing networks by providing support to Member States so they can contribute observational seismic, sea level and GPS data to CARIBE-EWS and install additional stations as required.	Member States WG 1	2011	0

Actions	Responsibility	Timeline	Estimated Costs
Hold an annual sea level course. Communication and maintenance issues of sea level station operations need to be addressed with consideration of multipurpose applications.	IOC Member States	2011–2013	$30,000/year
Hold an annual WG 1 meeting.	IOC Tsunami Unit Member States	2011–2013	$30,000/year
Establish and maintain online tools to share information on the status of core sea level, seismic and GPS stations contributing to the CARIBE EWS both to the TWC and IRIS.	CTWP	2011	
Hold an annual seismic network short-course on station operations and best practices. Choose agenda based on current technical needs.	IOC Member States	Annual	$30,000/year
Submit recommendations to update the seismic, sea level and seismic station requirements included in Doc. ICG/CARIBE-EWS-V.1 for CORE station minimum construction requirements, including: vault construction, power, and communication infrastructure.	SRC OSOP IPGP USGS PRSN	Ongoing	$0
Engage with the CocoNet project in the installation and integration of GPS stations in the Caribbean and Adjacent Regions.	WG 1	2011–2013	$0
Optimize and explore alternatives for robust seismic and sea level data sharing between networks and warning and data centres and develop tools for the visualization and analysis of the data.	US (GOES) Member States IOC		$100,000

Table 3. Action Plan for the Inter-sessional Period 2011–2014

5.4 TSUNAMI SERVICES

A main component of a Tsunami Warning System is the timely monitoring, detection, evaluation and communication of potential tsunami events to the threatened population (Figure 9). These tsunami services require the coordination between the tsunami warning centre(s), the designated CARIBE-EWS tsunami warning focal points and the local notification structure.

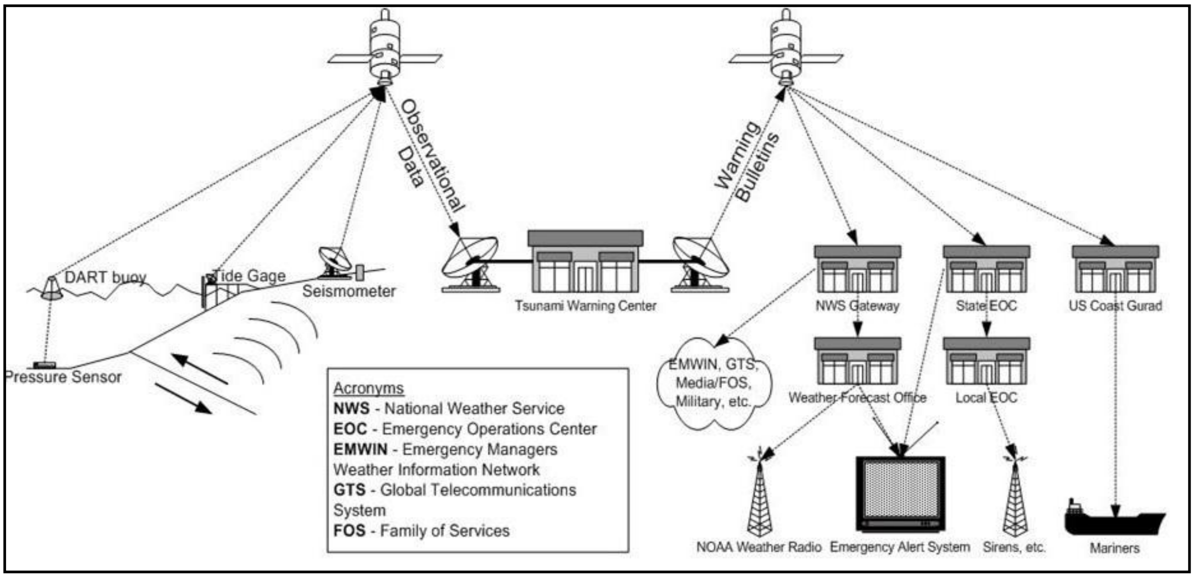

Figure 9. Schematic diagram of a tsunami warning system, from detection and observation to alerting the population at risk

5.4.1 Introduction

Since 2005, the Pacific Tsunami Warning Center of the US National Weather Service has served as the Interim Tsunami Watch Provider for the region with the exception of Puerto Rico and the US Virgin Islands which are currently served by the West Coast and Alaska Tsunami Warning Center (Figure 10). Based on the guidance provided by these tsunami warning centres to the designated tsunami warning focal points, these are then responsible for issuing alerts within their areas of responsibility.

Figure 9. Area of responsibility of tsunami warning centres currently serving the CARIBE-EWS region

In 2007, the Second Session of the Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS-II), held in Cumana, Venezuela, from 12 to 14 March 2007 recommended the establishment of a regional tsunami warning center in the Caribbean to serve the Caribbean and the Adjacent Regions. In 2009, the Fourth Session of the ICG/CARIBE-EWS (ICG/CARIBE-EWS-IV) held in Fort-de-France, Martinique, approved the requirements for this Centre; while in 2010, the US established the Caribbean Tsunami Warning Program, collocated with the Puerto Rico Seismic Network at the University of Puerto Rico at Mayagüez. In 2011, the Seventh Session of the ICG/CARIBE-EWS (ICG/CARIBE-EWS-VII) held in Willemstad, Curaçao, endorsed the phased approach of the USA towards the potential establishment of the Caribbean Tsunami Warning Center. In the meantime, other Member States have also developed capabilities for the provision of tsunami services.

The Sixth Session of the ICG/CARIBE-EWS (ICG/CARIBE-EWS-VI) held in Santo Domingo, Dominican Republic, from 26 to 29 April 2011, encouraged the continued efforts and technical advances made by Nicaragua and the Bolivarian Republic of Venezuela in the establishment of an additional regional tsunami warning centre in support of the Caribbean Tsunami Warning Center.

The activities of the centres are to acquire, record and process earthquake data for the rapid initial warning (origin time, latitude, longitude, depth and magnitude); to compute the arrival time of the tsunami in the corresponding forecasting points; to collect, record, process sea level data to confirm; to monitor or cancel the warning; to transmit messages to the tsunami warning focal points; to coordinate with other tsunami warning centres, establish standard operating procedures, establish tsunami research programs; and to support outreach, education and preparedness in the region. These requirements have laid out in the document ICG/CARIBE-EWS-IV/13. A Caribbean Tsunami Warning Center in the region is also needed to provide the fastest possible tsunami alerts for the timely response of the populations of the avoid unnecessary evacuations which can have a significant impact on the economies of the region.

In the past, tsunami products were based strictly on the magnitude of the earthquakes and the travel times of the potential tsunami. If tsunamis were detected, the arrival times and wave heights were noted. Different terms were used to describe the threat level. In order to make informed decisions regarding the response of the public to events (e.g. whether or not to evacuate), the local stakeholders would greatly benefit from knowing the expected impact. This in combination with the confusion caused by the use of alert level terms has led to the development of new products that will avoid such terms, but also provide forecast levels of impact. The alert levels would be the sole responsibility of each country or territory.

Numerical forecasts provided in the new product suite will still be conservative but should significantly reduce over-warning. In addition, by giving an expected level of impact they allow local authorities to design appropriate levels of response. For example, the response for a smaller tsunami might be to just clear beaches and harbours versus evacuating the entire coastal zone.

Lastly, the new products suite includes graphical products: maps that show the forecast directionality of the tsunami energy, the forecast position of the initial wave through time, as well as the expected maximum wave amplitudes at the coast. Graphical products provide more information at a much greater level of detail than is possible with text products. They are also helpful for communicating the threat quickly when time is of the essence.

The greatest unknown about the tsunami in real-time (and even later) is its source. How did the seafloor deform? How much was it displaced up or down and over what areas to generate the tsunami? Models all make assumptions about the source based upon the seismic analysis or later upon nearby sea level gauge readings. But they only approximate the real source. The second limitation is in observing the tsunami prior to impact – not only to confirm and measure the waves but to help constrain the forecast models. There are still too few sea level gauges in the Caribbean and for many sources only one or two readings may be possible before the tsunami crosses the sea. The third greatest limitation is how the tsunami will interact with the coast. In most cases, a general approximation must be used. Even when detailed coastal inundation models are available, properly capturing coastal resonances, trapped wave energy, and multiple wave interactions after even a few wave cycles is not possible. For these reasons, the forecast model information provided in the new products should be viewed with some caution, taking into consideration limitations described here and explained further in this document.

The impact of tsunamis and other marine-related hazards can be substantially mitigated if timely warnings are issued to the population by the TWS. It is necessary to implement a protocol for warning, dissemination and communication. The protocol needs to address the local, regional and distant tsunami scenarios. The messages of the tsunami warning focal point to the designated national authority need to be short and clear.

Each country has to define standard operating procedures (SOPs) to disseminate the messages between focal point, designated national authority and communities, and govern cooperation between the designated national authority and the media. The latter is important to so that the media does not issue warnings that may well be inappropriate, before the designated national authority has made a decision. Each country should maintain at least two independent methods of communication, such as EMWIN (Emergency Management Weather Information Network), other dedicated satellite communication lines, and GTS so as to assure receipt of messages from the regional warning center in a timely fashion at any designated TWFP.

The regional centre should be required to issue regular communication tests. The focal point of each country is required to participate in the communication test of the regional centre by responding to questions asked in the communications test messages and by sending their reply back to the regional centre. These procedures will help to insure robust communications between the regional centre and focal points in the region.

At the Sixth Session of the ICG/CARIBE-EWS in April 2011, the ICG agreed to revise the ICG/CARIBE-EWS Communications Plan to include the following schedule for PTWC TWFP communication tests:

(i) Hold communication tests on the first Thursday of every month at 15:30 (UTC/GMT) as from 1st September 2011. Members States TWFP's should report only issues and errors during these monthly tests to the PTWC and IOC Secretariat;

(ii) Hold twice yearly TWFP "No Notice" verification communication tests. For these tests, Member States' TWFPs shall verify PTWC communication (and all means received and not received) within one (1) hour of the "No Notice" test;

(iii) all verifications by Countries for issues from monthly tests shall be sent to the PTWC within one (1) hour to facilitate "active action" or "repetitive action" education on a monthly basis;

(iv) The ICG instructed WG 3 on Warning Dissemination and Communication to evaluate automated feedback mechanisms for communication tests and report to the Seventh session of the ICG.

Public education is required so that populations in low-lying coastal areas understand the warning signs indicative of a possible tsunami threat. For example, if people in low-lying coastal areas feel a strong ground shake or see the ocean recede unnaturally, they should move inland and uphill as quickly as possible, as these observations may indicate a tsunami threat exists. Even a national warning centre may not be able to transmit warnings quickly enough to warn people in close proximity to the epicentre.

5.4.2 Action Plan

Action	Responsible	Timeline	Cost
Establish the Caribbean Tsunami Warning Center to be collocated with the Puerto Rico Seismic Network at the University of Puerto Rico at Mayagüez.	USA	(TBD)	$12,000,000 (construction of facilities) $3,000,000/year for operations
Establishment of additional regional tsunami warning centres in support of the Caribbean Tsunami Warning Center.	Nicaragua Bolivarian Republic of Venezuela	(TBD)	0
Establish a Task Team which includes the ICG Officers, Director of the PTWC, Manager of CTWP to provide feedback during development of new products, validates these new products, procedures and implementation.	ICG Officers PTWC CTWP	2013	0
Update the PTWC Users Guide for the Caribbean and Adjacent Regions.	PTWC CTWP	2013	
Develop regional training for the new products, including the development of standard operating procedures securing that at least 2 national officers of each Member States get trained.	CTIC CTWP	2013–2014	

Table 4. Action Plan for Tsunami Services

5.5 PUBLIC AWARENESS, EDUCATION AND RESILIENCE

5.5.1 Introduction

Timely and accurate dissemination of warnings is an essential part of an end-to-end warning system and requires the development of inter-institutional agreements among stakeholder organizations as well as SOPs for activation of the warning process. A SOP is a set of written instructions which document a routine, or repetitive work processes followed within an organization. Organizational Tsunami SOPs can be utilised to ensure that warnings will be transmitted from the tsunami warning focal point out to critical response agencies and down to vulnerable, at-risk communities. Protocols define (i) the roles and responsibilities of each organization; (ii) paths of communication between organizations, including which organizations communicate with others and how; and (iii) the hierarchy of decision makers, for example, for whether, where and when to call for evacuations.

The process of protocol development is a very practical tool for walking participating agencies through the identification of all necessary stakeholders, the necessary steps that must be taken to prepare for and respond to an event, and the recipients of warning messages. Many countries in the Caribbean and adjacent regions already have experience in developing protocols for slower onset types of hydro-meteorological events such as tropical storms and hurricanes. The task is now to modify and/or develop these for a rapid on-set event such as a tsunami.

SOP development was implemented in some CDEMA Participating States (Antigua and Barbuda, Barbados, Grenada, and Jamaica) with funding supplied by the Office of Foreign Disaster Assistance of the United States Agency for International Development (USAID). New funding has been secured by the United Nations Development Programme (UNDP) for SOP development in the framework of CTIC for the Member States of the Organization of Eastern Caribbean States (OECS) and need to be identified for adjacent Central American, South American (as well as Spanish and French-speaking) Member States.

Public awareness and preparedness activities have a double function: they work to safeguard the vulnerable population, as well as creating support for the preparedness and response structure. Public events that mark specific historical events can galvanize public awareness and support preparedness, e.g. the 29 July 1967 Caracas earthquake is commemorated each year with civic and educational preparedness campaigns, such as drills, and contests geared towards sustaining a culture of prevention.

A number of institutions and communities around the world have developed valuable information that can be reused, translated and/or adapted to the Caribbean and its diverse population and cultures. For example, the ITIC website (www.tsunamiwave.info) has tsunami school curriculum in Spanish and English (developed by Hydrographic and Oceanographic Service of the Navy of Chile [SHOA]). There are also materials geared towards the media and decision-makers. A concerted effort needs to be made so that multi-hazard stakeholder groups around the region – at national, local and community levels – can be made aware of these materials and encouraged to adapt them to their needs.

Another way to promote public awareness is to adapt already developed preparedness and mitigation models to the Caribbean and support their implementation in each Member State. The city of Mayagüez (population: 105,000), Puerto Rico, is the first Caribbean community to be declared “Tsunami Ready”, which is a program that has been developed by the US National Weather Service (NWS), a division of NOAA. Working closely with the National Weather Service forecast office in San Juan, as well as the Puerto Rico Seismic Network, Mayagüez completed a rigorous set of warning and evacuation criteria to meet the guidelines for TsunamiReady recognition.

To be recognized as "TsunamiReady", a community must: Establish a 24 hour warning point and emergency operations center; develop multiple ways to receive tsunami warnings and alert the public; develop a formal tsunami hazard plan and conduct emergency exercises; promote public readiness through community education.

TsunamiReady communities must be re-certified every 3 years. More information on TsunamiReady program is available at the NWS website: http://www.tsunamiready.noaa.gov/. The Caribbean islands have also taken on board the Tsunami Smart brand, with many educational materials developed for dissemination as well. Countries may wish to decide among the preparedness programmes for use in their national setting.

Finally, Caribbean universities occupy a unique role within their countries and regions, in terms of providing expertise, fomenting research and developing leadership on a range of disaster and risk management themes, including the tsunami hazard. There are newly formed and forming centres of excellence and initiatives that should be encouraged to incorporate tsunamis into their multi-hazard fields of study.

The launching of a Caribbean Tsunami Information Center (CTIC), modelled on the ITIC and Jakarta Tsunami Information Centre (JTIC), was proposed at the ICG/CARIBE-EWS-I and endorsed at the Second Session of the ICG/CARIBE-EWS held in Cumana, Venezuela, from 12 to 14 March 2007 (ICG/CARIBE-EWS-II). Such an institution would be indispensable for supporting the activities discussed in items 1 and 2, and would be complementary to a regional warning centre on outreach and public awareness. The Government of Barbados has signed the agreement with UNESCO to host the CTIC and at the Sixth and Seventh Session of the ICG/CARIBE-EWS (ICG/CARIBE-EWS-VI, ICG/CARIBE-EWS-VII), the Intergovernmental Coordination Group agreed to address the issue of Member States financial contributions to the CTIC

Funding has been secured for CTIC establishment, and the CTIC will be operational in the second quarter of 2013. UNESCO has allocated funding for the salary of the interim CTIC Director for the next 3 years, and Barbados has arranged for office accommodation and associated services for the CTIC.

5.5.2 Plan of Action[2]

Action	Responsible	Timeline
Improved coordination of public education initiatives among Member States.	WG 4 Chair, CTIC Board, CTIC Director.	2013–2016
Existing earthquake, hurricane, volcanic and other multi-hazard protocols can be integrated with new tsunami protocols.	Multi-country, multi-agency.	Ongoing

[2] This Plan of Action should be complemented with actions proposed by the Tsunami Public Awareness and Educations Strategy for the Caribbean and Adjacent Regions (IOC, 2013)

Action	Responsible	Timeline
Engage the regional tertiary institutions (UNICA, University of the West Indies, UASD, etc.) to support tsunami education, awareness, preparedness, and mitigation activities.	WG Chairs, ICG Chairs, Technical Secretary.	2013–2015
Develop a region wide recognition program for coastal tsunami communities that have taken specific measures to prepare for tsunamis, using best practices like Tsunami Smart, TsunamiReady.	WG 4 and CTIC	By ICG/CARIBE-EWS-IX
Identify and pursue potential funding sources and technical assistance for CTIC operating expenses in the public and private sectors.	UNESCO Tsunami Unit, Member States.	Ongoing

Table 5. Action Plan for Tsunami Awareness, Education and Resilience
(This table should be updated mainly through the CTIC work plan)

6. REFERENCES

Geist, E.L., and Parsons, T., 2009, Assessment of source probabilities for potential tsunamis affecting the U.S. Atlantic Coast, Marine Geology, v. 264, p. 98-108, doi:10.1016/j.margeo.2008.08.005.

Gutscher, M. A., 2013, Is the Antilles subduction capable of generating a great earthquake and tsunami?, Caribbean Waves 2, Guadeloupe, January 22-25.

Hyman, G., 2005. Centro Internacional de Agricultura Tropical (CIAT), United Nations Environment Program (UNEP), Center for International Earth Science Information Network (CIESIN), Columbia University, and the World Bank Latin American and Caribbean Population Database. Version 3.
Available from http://www.na.unep.net/siouxfalls/datasets/datalist.php or http://gisweb.ciat.cgiar.org/population/dataset.htm

Intergovernmental Oceanographic Commission (IOC), 2013, Tsunami Public Awareness and Educations Strategy for the Caribbean and Adjacent Regions. IOC Technical Series No.107. Paris, UNESCO.

Manaker, D.M., Calais, E., Freed, A.M., Ali, S.T., Przybylski, P., Mattioli, G., Jansma, P., Prépetit, C., and de Chabalier, J.B., 2008. Interseismic plate coupling and strain partitioning in the northeastern Caribbean, Geophys. J. Int., 174, 889-903.

Mann, P., Calais, E., Ruegg, J-C., DeMets, C., Jansma, P.E., and Mattioli, G.S., 2002. Oblique collision in the northeastern Caribbean from GPS measurements and geological observations, Tectonics 21, doi:10.1029/2001TC001304.

Mann, P., Hippolyte, J-C., Grindlay, N.R., and Abrams, L.J., 2005. Neotectonics of southern Puerto Rico and its offshore margin, Geol. Soc. Amer. Special Paper 385, 173-214.

McCann, W.R., and Sykes, L.R., 1984. Subduction of aseismic ridges beneath the Caribbean Plate: implications for the tectonics and seismic potential of the northeastern Caribbean, J. Geophys. Res., 89, 4493-4519.

McNamara, D.E., Christa von Hillebrandt-Andrade, P. Earle, R. Buland, Seismic Capabilities of an International Caribbean Tsunami Warning System, 2008, Seismological Research Letters, 80, 2, p. 344.

McNamara, D., J. McCarthy, and H. Benz, Improving Earthquake and Tsunami Warning for the Caribbean Sea, Gulf of Mexico and the Atlantic Coast, U.S. Geol. Surv. Fact Sheet, 2006-3012, 4 p, 2006. (http://pubs.usgs.gov/fs/2006/3012/).

Okal, E., 2013, Tsunamis as normal modes of the Earth, and a venture into extracurricular geophysics. Caribbean Waves 2, Guadeloupe, January 22-25

Proenza, X.W., and G.A. Maul, 2010, Tsunami hazard and total risk in the Caribbean basin, Science of tsunami hazards, 29, 2, 70-77

ANNEX I

SEA LEVEL STATIONS
AS OF APRIL 2013

COUNTRY	STATION LOCATION	STATION CODE (IOC)	STATUS
Antigua and Barbuda	Barbuda	barb	Contributing RTX
Bahamas	Settlement Point	setp1	Contributing RTX
Barbados	Port St. Charles	ptsc	Contributing RTX
Bermuda	St. Georges Island	bmda	Contributing RTX
Caribbean Sea	DART 42407		Contributing RTX
Colombia	San Andres	sana	Contributing RTX
Colombia	Santa Marta	sama	Contributing RTX
Costa Rica	Limón	limon	Contributing RTX
Curacao	Willemstad	will	Contributing RTX
Dominica	Roseau	rose	Contributing RTX
Dominican Republic	Barahona	bara	Contributing RTX
Dominican Republic	Puerto Caucedo/San Andres/Santo Domingo	sdom	Contributing RTX
Dominican Republic	Puerto Plata	ptpl	Contributing RTX
Dominican Republic	Punta Cana	ptca	Contributing RTX
E. Puerto Rico Trench	DART 41421		Contributing RTX
E. South Carolina	DART 41424		Contributing RTX
French Guiana	Ile Royale	iler	Contributing RTX
Grenada	Prickly Bay	pric	Contributing RTX

COUNTRY	STATION LOCATION	STATION CODE (IOC)	STATUS
Guadeloupe	Grande Anse Marina Harbour, Désirade Island	desi	Contributing RTX
Guadeloupe	Point a Pitre Harbour	ptpt	Contributing RTX
Gulf of Mexico	DART 42409		Contributing RTX
Haiti	Cap Haitien	caph	Contributing RTX
Martinique	Fort de France Harbour	ftfr	Contributing RTX
Mexico	Celestun	clst	Contributing RTX
Mexico	Ciudad del Carmen	ccar	Contributing RTX
Mexico	Frontera	frtr	Contributing RTX
Mexico	Isla Mujeres	imuj	Contributing RTX
Mexico	Puerto Morelos	pumo	Contributing RTX
Mexico	Tuxpan	tuxp	Contributing RTX
Mexico	Veracruz	vera	Contributing RTX
NE Bermuda	DART 44401		Contributing RTX
Panama	El Porvenir	elpo	Contributing RTX
Puerto Rico	Aguadilla		Out of Service
Puerto Rico	Arecibo	arac	Contributing RTX
Puerto Rico	Culebra Island	cule	Contributing RTX
Puerto Rico	Fajardo	faja	Contributing RTX
Puerto Rico	Isabel II, Vieques	isab	Contributing RTX
Puerto Rico	La Esperanza, Vieques	vieq	Contributing RTX

COUNTRY	STATION LOCATION	STATION CODE (IOC)	STATUS
Puerto Rico	Magueyes Island	magi	Contributing RTX
Puerto Rico	Mayagüez	maya	Contributing RTX
Puerto Rico	Mona Island	mona2	Contributing RTX
Puerto Rico	Peñuelas	penu	Contributing RTX
Puerto Rico	San Juan	sanj	Contributing RTX
Puerto Rico	Yabucoa	yabu	Contributing RTX
SE New York	DART 44402		Contributing RTX
USVI	Charlotte Amalie, St. Thomas	amal	Contributing RTX
USVI	Christiansted Harbor, St. Croix	stcr	Contributing RTX
USVI	Lameshur Bay, St. John	lame	Contributing RTX
USVI	Lime Tree Bay, St. Croix	lime	Contributing RTX
W. Puerto Rico Trench	DART 41420		Contributing RTX
Bahamas	Lee Stocking Island, Exuma		Existing
Bahamas	Matthew Town, Inagua		Existing
Bahamas	Nassau Harbour, New Providence		Existing
Bahamas	Treasure Cay, Abaco		Existing
Barbados	Bridgetown Port		Existing
Barbados	Pelican Fort		Existing
Belize	Belize		Existing

COUNTRY	STATION LOCATION	STATION CODE (IOC)	STATUS
Belize	Carrie Bow Cay		Existing
British Virgin Islands	Road Town Harbor, Tortola		Existing
Colombia	Capurganá		Existing
Colombia	Cartagena		Existing
Colombia	Islas del Rosario		Existing
Cuba	Cabo Cruz		Existing
Cuba	Cabo San Antonio		Existing
Cuba	Gibara		Existing
Cuba	Isabela de Sagua		Existing
Cuba	Manzanillo		Existing
Guatemala	Puerto Santo Tomas de Castilla		Existing
Guyana	Harbour Master Boathouse	HMB	Existing
Guyana	Market Place	Georgetown	Existing
Jamaica	Port Royal		Existing
Martinique	Le Precheur Harbour		Existing
Mexico	Progreso		Existing
Panama	Bocas del Toro		Existing
Panama	Galeta Point		Existing
Panama	Limon Bay (replaced Coco Solo which replaces Portobelo, reccomended initially by IAS, given close location)		Existing

COUNTRY	STATION LOCATION	STATION CODE (IOC)	STATUS
St. Kitts	Baseterre		Existing
St. Lucia	Castries		Existing
St. Vincent	Kingstown		Existing
Cuba	Guantanamo		Gap
Dominican Republic	Bayahibe		Gap
Dominican Republic	Pedernales		Gap
Honduras	Cochino Pequeño		Gap
Honduras	Swan Island		Gap
Montserrat	Montserrat		Gap
Turks and Caicos	South Caicos		Gap
Venezuela	Aves Island		Gap
Venezuela	Punta Arenas, Margarita Island		Gap
Jamaica	Discovery Bay, Jamaica		Gap (Damaged)
Nicaragua	Blue Fields		Gap/Non operational
Nicaragua	Puerto Cabezas		Gap/Non operational
Barbados	Conset Bay		Non operational-CZMU
Barbados	Speightstown		Non operational-CZMU
Antigua and Barbuda	Parham (Camp Blizard), Antigua		Non-operational
Guyana	Rosignol		Non-operational
Costa Rica	Puntarenas		Planned

COUNTRY	STATION LOCATION	STATION CODE (IOC)	STATUS
Cuba	Casilda		Planned
Cuba	Maisí		Planned
Cuba	Siboney		Planned
Dominican Republic	Bahía de Luperón		Planned
Dominican Republic	Bahía de Samaná		Planned
Dominican Republic	Puerto de Santo Domingo		Planned
Grand Cayman Island	Georgetown		Planned
Grenada	Sauteurs		Planned
Grenada	The Sisters Island,		Planned
Guadeloupe	Harbour Deshaies		Planned
Haiti	Port au Prince		Planned
Martinique	Le Robert		Planned
Nicaragua	Corn Island		Planned
Trinidad and Tobago	Charlotteville	Tobago	Planned
Trinidad and Tobago	Point Fortin	Trinidad	Planned
Trinidad and Tobago	Point Galeota	Trinidad	Planned
Trinidad and Tobago	Port Of Spain	Trinidad	Planned
Trinidad and Tobago	Scarborough	Tobago	Planned
Guyana	Parika		Unknown
Venezuela	La Guaira		Unknown

ANNEX II

SEISMIC STATIONS

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Antarctica	Palmer Station	PMSA	IU	Contributing-RTX
Antigua and Barbuda	Willy Bob	ANWB	CU	Contributing-RTX
Barbados	Gun Hill	BBGH	CU	Contributing-RTX
Belize				Gap
Brazil	Pitinga	PTGA	IU	Contributing-RTX
Brazil	Riachuelo	RCBR	IU	Contributing-RTX
Brazil	Samuel	SAML	IU	Contributing-RTX
Cape Verde	Santiago Island	SACV	II	Contributing-RTX
Chile	Las Campanas Astronomical Observatory	LCO	IU	Contributing-RTX
Colombia	Capurgana	CAP2	CM	Contributing-RTX
Colombia	Santa Helena	HEL	CM	Contributing-RTX
Colombia	Monteria	MON	CM	Contributing-RTX
Colombia	Uribia	URI	CM	Contributing-RTX
Colombia	Cerro Kennedy	KEN	CM	Existing

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Colombia	Cerro El Rosal	ROSC	CM	Existing
Colombia		OCA	CM	Planned
Costa Rica	Heredia	HDC	G	Contributing-RTX
Costa Rica	Las Juntas de Abangares	JTS	II	Contributing-RTX
Costa Rica		BATAN	OV	Contributing-RTX
Costa Rica		CDITO	OV	Contributing-RTX
Costa Rica		HZTE	OV	Contributing-RTX
Costa Rica	Cocos Island			Existing
Cuba	Guantanamo Bay	GTBY	CU	Contributing-RTX
Cuba	Cascorro	CCCC		Existing
Cuba	Manicaragua	MGV		Existing
Cuba	Soroa	SOR		Existing
Denmark	Greenland	SFJD	IU	Contributing-RTX
Dominican Republic	Sabaneta Dam	SDDR	CU	Contributing-RTX
Dominican Republic	Santiago	SC01 (replaced PUCM)	DR	Contributing-RTX
Dominican Republic	Santo Domingo	SDD	DR	Contributing-RTX
Dominican Republic	Punta Cana	PCDR	PR	Contributing-RTX

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Dominican Republic	Samana	SMN1	PR	Contributing-RTX
Dominican Republic	Jimani	JIDR	DR	Non-operational
Dominica	La Plaine	DLPL	TR	Contributing-RTX
Ecuador	Otavalo	OTAV	IU	Contributing-RTX
Ecuador	Puerto Ayora	PAYG	IU	Contributing-RTX
El Salvador	San Salvador	SNET	SV	Contributing-RTX
France	Fort de France	FDF*	G	Contributing-RTX
France	Montagne des Peres	MPG	G	Contributing-RTX
France	Deshaies	DHS	WI	Contributing-RTX
France	Desirade	DSD	WI	Contributing-RTX
Grenada	Grenada	GRGR	CU	Contributing-RTX
Guatemala	El Apazote	APG	GT/CTBTO	Existing
Haiti	Leogane	LGNH	CN	Contributing-RTX
Haiti	Port au Prince	PAPH	CN	Contributing-RTX
Haiti	Central			Gap
Haiti	North			Gap

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Honduras	Honduras	TGUH	CU	Contributing-RTX
Honduras	Caribbean Coast			Gap
Honduras	Swan Island			Gap
Iceland	Iceland	BORG	II	Contributing-RTX
Jamaica	Mount Denham	MTDJ	CU	Contributing-RTX
Jamaica	Eastern			Gap
Jamaica	Western			Gap
Kenya	Kenya	KMBO	IU	Contributing-RTX
Mexico	Sierra la Laguna	SLBS (substituted LPIG)	IU	Contributing RTX
Mexico	Juriquilla	JRQG	MG	Contributing RTX
Mexico	Mexico	UNM	G	Contributing-RTX
Mexico	Tepich	TEIG	IU	Contributing-RTX
Mexico		LNIG	MX	Contributing-RTX
Mexico		LVIG (replace TUIG)	MX	Contributing-RTX
Mexico	Yucatan	MYIG	MX	Contributing-RTX
Mexico	Tuxtla Gutiérrez	TGIG	MX	Contributing-RTX

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Mexico	Pueblo Juarez	CLMX, BBPJ	UC	Contributing-RTX
Netherlands	Saba	SABA	NA	Contributing-RTX
Netherlands	St. Eustatia	SEUS	NA	Contributing-RTX
Netherlands	St. Maarten	SMRT	NA	Contributing-RTX
Netherlands		AUA1	PR	Contributing-RTX
Nicaragua	Boaco	BOAB	GE	Contributing-RTX
Nicaragua	Acoyapa	ACON	NU	Contributing-RTX
Nicaragua	Bluefields	BLUN	NU	Contributing-RTX
Nicaragua	L a Esperanza	ESPN	NU	Contributing-RTX
Nicaragua	INETER Managua	MGAN	NU	Contributing-RTX
Norway	Kongsberg	KONO	IU	Contributing-RTX
Panama	Barro Colorado	BCIP	CU	Contributing-RTX
Panama	Volcán Baru	BRU2	PA	Contributing-RTX
Peru	Nana	NNA	II	Contributing-RTX
Portugal	Azores	CMLA	II	Contributing-RTX

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Spain	San Pablo de los Montes	PAB	IU	Contributing-RTX
St. Kitts	Bayfords	SKI	TR	Contributing-RTX
St. Lucia	Moule a chique	MCLT	TR	Contributing-RTX
St. Vincent	Belmont	SVB	TR	Contributing-RTX
Trinidad and Tobago	Speyside	TOSP	TR	Contributing-RTX
Trinidad and Tobago	St. Augustine	TRN*	TR	Planned
Turkey	Ankara	ANTO	IU	Contributing-RTX
Uganda	Mbarra	MBAR	II	Contributing-RTX
UK	The Bluff	CBCY	CY	Contributing RTX
UK	Frank Sound	FSCY	CY	Contributing RTX
UK	Blossom Village	LCCY	CY	Contributing RTX
UK	West Bay	WBCY	CY	Contributing RTX
UK	Grand Turks	GRTK	CU	Contributing-RTX
UK	Butt Crater	ASCN	II	Contributing-RTX
UK	East Falkland Islands	EFI	II	Contributing-RTX

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
UK	Scotland	ESK	II	Contributing-RTX
UK	Hope Point	HOPE	II	Contributing-RTX
UK	Horse Pasture	SHEL	II	Contributing-RTX
UK	St. George's	BBSR	IU	Contributing-RTX
UK		TRIS	IU	Contributing-RTX
UK	Montserrat	MBWH	MO (red sismica)	Contributing-RTX
UK	Anegada	ABVI	PR	Contributing-RTX
USA	Pinon Flats	PFO	II	Contributing-RTX
USA	Albuquerque	ANMO	IU	Contributing-RTX
USA	Florida	DWPF	IU	Contributing-RTX
USA	Hockley	HKT	IU	Contributing-RTX
USA	Pohakuloa Training Area	POHA	IU	Contributing-RTX
USA	Cayey	SJG	IU	Contributing-RTX
USA	Standing Stone	SSPA	IU	Contributing-RTX
USA	Tucson	TUC	IU	Contributing-RTX

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
USA	Waverly	WVT	IU	Contributing-RTX
USA	Aguadilla	AGPR	PR	Contributing-RTX
USA	Arecibo	AOPR	PR	Contributing-RTX
USA	Cubuy	CBYP	PR	Contributing-RTX
USA	Country Day School	CDVI	PR	Contributing-RTX
USA	Cabo Rojo	CRPR	PR	Contributing-RTX
USA	Culebra	CUPR (replaces CULB)	PR	Contributing-RTX
USA	Humacao	HUMP	PR	Contributing-RTX
USA	Isla Caja de Muertos	ICMP (replaced ICM)	PR	Contributing-RTX
USA	Isla Mona	IMPR	PR	Contributing-RTX
USA	Mayagüez	MPR	PR	Contributing-RTX
USA	Monte Pirata	MTP	PR	Contributing-RTX
USA	Brewton	BRAL (replaces LTL)	US	Contributing-RTX
USA	Kingsville	KVTX	US	Contributing-RTX
Venezuela	Santo Domingo	SDV	IU	Contributing-RTX

COUNTRY	LOCALITY	STATION CODE	FDSN NETWORK CODE	STATUS
Venezuela	El Baul	BAUV	VE	Contributing-RTX
Venezuela	Dabajuro	DABV	VE	Contributing-RTX
Venezuela	Jacura	JACV	VE	Contributing-RTX
Venezuela	Oritupano	ORIV	VE	Contributing-RTX
Venezuela	Puerto la Cruz	PCRV	VE	Contributing-RTX
Venezuela	Llanito	FUNV	VE	Gap
Venezuela	Guiria	GUIV	VE	Gap
Venezuela	Guri	GURV	VE	Gap
Venezuela	Isla de Aves	IAW	VE	Gap
Zambia	Lusaka	LSZ	IU	Contributing-RTX

ANNEX III

LIST OF ACRONYMS

CARIBE-EWS	Tsunami and Other Coastal Hazards Warning System in the Caribbean and Adjacent Regions (UNESCO/IOC)
CARICOM	Caribbean Community
CDEMA	Caribbean Disaster Emergency Management Agency
COCONet	Continuously Operating Caribbean GPS Observational Network project
CTBTO	Comprehensive-Test-Ban Treaty Organization
CTIC	Caribbean Tsunami Information Center
CTS	CARIBE-EWS Technical Secretary
CTWP	Caribbean Tsunami Warning Program
DART	Deep-ocean Assessment and Reporting of Tsunami Ocean buoys
DCS	Data Collection System
DMC	Data Management Center
EWS	Early Warning System
GOES	Geostationary Operational Environmental Satellite
GTS	Global Telecommunication System
ICG	Intergovernmental Coordination Group
ICG/CARIBE-EWS	Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (UNESCO/IOC)
ImPlan	Implementation Plan
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IRIS	Incorporated Research Institutions for Seismology
JTIC	Jakarta Tsunami Information Centre (Indonesia)
NEIC	National Earthquake Information Center (U.S.A.)
NOAA	National Oceanic and Atmospheric Administration (U.S.A.)

NSF	National Science Foundation (U.S.A.)
NWS	National Weather Service (U.S.A.)
OBS	ocean bottom seismometers
OECS	Organization of Eastern Caribbean States
PRSN	Puerto Rico Seismic Network
PTWC	Pacific Tsunami Warning Center
RSN	Regional Seismic Networks
RTWC	Regional tsunami warning centre
SHOA	Hydrographic and Oceanographic Service of the Navy of Chile
SOP	Standard Operation Procedure
TCP/IP	Transmission Control Protocol/Internet Protocol
TNC	Tsunami National Contact
TSU	Tsunami Unit of the IOC
TTs	Task Teams
TWFP	Tsunami Warning Focal Point
TWS	Tsunami Warning System
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USGS	United States Geological Survey
VSAT	Very Small Aperture Terminals
WCATWC	West Coast and Alaska Tsunami Warning Center
WG	Working Group
WMO	World Meteorological Organization

IOC Technical Series

No.	Title	Languages
1	Manual on International Oceanographic Data Exchange. 1965	(out of stock)
2	Intergovernmental Oceanographic Commission (Five years of work). 1966	(out of stock)
3	Radio Communication Requirements of Oceanography. 1967	(out of stock)
4	Manual on International Oceanographic Data Exchange - Second revised edition. 1967	(out of stock)
5	Legal Problems Associated with Ocean Data Acquisition Systems (ODAS). 1969	(out of stock)
6	Perspectives in Oceanography, 1968	(out of stock)
7	Comprehensive Outline of the Scope of the Long-term and Expanded Programme of Oceanic Exploration and Research. 1970	(out of stock)
8	IGOSS (Integrated Global Ocean Station System) - General Plan Implementation Programme for Phase I. 1971	(out of stock)
9	Manual on International Oceanographic Data Exchange - Third Revised Edition. 1973	(out of stock)
10	Bruun Memorial Lectures, 1971	E, F, S, R
11	Bruun Memorial Lectures, 1973	(out of stock)
12	Oceanographic Products and Methods of Analysis and Prediction. 1977	E only
13	International Decade of Ocean Exploration (IDOE), 1971-1980. 1974	(out of stock)
14	A Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment and Baseline Study Guidelines. 1976	E, F, S, R
15	Bruun Memorial Lectures, 1975 - Co-operative Study of the Kuroshio and Adjacent Regions. 1976	(out of stock)
16	Integrated Ocean Global Station System (IGOSS) General Plan and Implementation Programme 1977-1982. 1977	E, F, S, R
17	Oceanographic Components of the Global Atmospheric Research Programme (GARP) . 1977	(out of stock)
18	Global Ocean Pollution: An Overview. 1977	(out of stock)
19	Bruun Memorial Lectures - The Importance and Application of Satellite and Remotely Sensed Data to Oceanography. 1977	(out of stock)
20	A Focus for Ocean Research: The Intergovernmental Oceanographic Commission - History, Functions, Achievements. 1979	(out of stock)
21	Bruun Memorial Lectures, 1979: Marine Environment and Ocean Resources. 1986	E, F, S, R
22	Scientific Report of the Interealibration Exercise of the IOC-WMO-UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open Ocean Waters. 1982	(out of stock)
23	Operational Sea-Level Stations. 1983	E, F, S, R
24	Time-Series of Ocean Measurements. Vol.1. 1983	E, F, S, R
25	A Framework for the Implementation of the Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment. 1984	(out of stock)
26	The Determination of Polychlorinated Biphenyls in Open-ocean Waters. 1984	E only
27	Ocean Observing System Development Programme. 1984	E, F, S, R
28	Bruun Memorial Lectures, 1982: Ocean Science for the Year 2000. 1984	E, F, S, R
29	Catalogue of Tide Gauges in the Pacific. 1985	E only
30	Time-Series of Ocean Measurements. Vol. 2. 1984	E only
31	Time-Series of Ocean Measurements. Vol. 3. 1986	E only
32	Summary of Radiometric Ages from the Pacific. 1987	E only
33	Time-Series of Ocean Measurements. Vol. 4. 1988	E only

(continued)

No.	Title	Languages
34	Bruun Memorial Lectures, 1987: Recent Advances in Selected Areas of Ocean Sciences in the Regions of the Caribbean, Indian Ocean and the Western Pacific. 1988	Composite E, F, S
35	Global Sea-Level Observing System (GLOSS) Implementation Plan. 1990	E only
36	Bruun Memorial Lectures 1989: Impact of New Technology on Marine Scientific Research. 1991	Composite E, F, S
37	Tsunami Glossary - A Glossary of Terms and Acronyms Used in the Tsunami Literature. 1991	E only
38	The Oceans and Climate: A Guide to Present Needs. 1991	E only
39	Bruun Memorial Lectures, 1991: Modelling and Prediction in Marine Science. 1992	E only
40	Oceanic Interdecadal Climate Variability. 1992	E only
41	Marine Debris: Solid Waste Management Action for the Wider Caribbean. 1994	E only
42	Calculation of New Depth Equations for Expendable Bathymerographs Using a Temperature-Error-Free Method (Application to Sippican/TSK T-7, T-6 and T-4 XBTS. 1994	E only
43	IGOSS Plan and Implementation Programme 1996-2003. 1996	E, F, S, R
44	Design and Implementation of some Harmful Algal Monitoring Systems. 1996	E only
45	Use of Standards and Reference Materials in the Measurement of Chlorinated Hydrocarbon Residues. 1996	E only
46	Equatorial Segment of the Mid-Atlantic Ridge. 1996	E only
47	Peace in the Oceans: Ocean Governance and the Agenda for Peace; the Proceedings of *Pacem in Maribus* XXIII, Costa Rica, 1995. 1997	E only
48	Neotectonics and fluid flow through seafloor sediments in the Eastern Mediterranean and Black Seas - Parts I and II. 1997	E only
49	Global Temperature Salinity Profile Programme: Overview and Future. 1998	E only
50	Global Sea-Level Observing System (GLOSS) Implementation Plan-1997. 1997	E only
51	L'état actuel de 1'exploitation des pêcheries maritimes au Cameroun et leur gestion intégrée dans la sous-région du Golfe de Guinée *(cancelled)*	F only
52	Cold water carbonate mounds and sediment transport on the Northeast Atlantic Margin. 1998	E only
53	The Baltic Floating University: Training Through Research in the Baltic, Barents and White Seas - 1997. 1998	E only
54	Geological Processes on the Northeast Atlantic Margin (8th training-through-research cruise, June-August 1998). 1999	E only
55	Bruun Memorial Lectures, 1999: Ocean Predictability. 2000	E only
56	Multidisciplinary Study of Geological Processes on the North East Atlantic and Western Mediterranean Margins (9th training-through-research cruise, June-July 1999). 2000	E only
57	Ad hoc Benthic Indicator Group - Results of Initial Planning Meeting, Paris, France, 6-9 December 1999. 2000	E only
58	Bruun Memorial Lectures, 2001: Operational Oceanography – a perspective from the private sector. 2001	E only
59	Monitoring and Management Strategies for Harmful Algal Blooms in Coastal Waters. 2001	E only
60	Interdisciplinary Approaches to Geoscience on the North East Atlantic Margin and Mid-Atlantic Ridge (10th training-through-research cruise, July-August 2000). 2001	E only
61	Forecasting Ocean Science? Pros and Cons, Potsdam Lecture, 1999. 2002	E only

No.	Title	Languages
62	Geological Processes in the Mediterranean and Black Seas and North East Atlantic (11th training-through-research cruise, July- September 2001). 2002	E only
63	Improved Global Bathymetry – Final Report of SCOR Working Group 107. 2002	E only
64	R. Revelle Memorial Lecture, 2006: Global Sea Levels, Past, Present and Future. 2007	E only
65	Bruun Memorial Lectures, 2003: Gas Hydrates – a potential source of energy from the oceans. 2003	E only
66	Bruun Memorial Lectures, 2003: Energy from the Sea: the potential and realities of Ocean Thermal Energy Conversion (OTEC). 2003	E only
67	Interdisciplinary Geoscience Research on the North East Atlantic Margin, Mediterranean Sea and Mid-Atlantic Ridge (12th training-through-research cruise, June-August 2002). 2003	E only
68	Interdisciplinary Studies of North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes (13th training-through-research cruise, July-September 2003). 2004	E only
69	Biodiversity and Distribution of the Megafauna / Biodiversité et distribution de la mégafaune. 2006 Vol.1 The polymetallic nodule ecosystem of the Eastern Equatorial Pacific Ocean / Ecosystème de nodules polymétalliques de l'océan Pacifique Est équatorial Vol.2 Annotated photographic Atlas of the echinoderms of the Clarion-Clipperton fracture zone / Atlas photographique annoté des échinodermes de la zone de fractures de Clarion et de Clipperton Vol.3 Options for the management and conservation of the biodiversity — The nodule ecosystem in the Clarion Clipperton fracture zone: scientific, legal and institutional aspects	E F
70	Interdisciplinary geoscience studies of the Gulf of Cadiz and Western Mediterranean Basin (14th training-through-research cruise, July-September 2004). 2006	E only
71	Indian Ocean Tsunami Warning and Mitigation System, IOTWS. Implementation Plan, 7–9 April 2009 (2nd Revision). 2009	E only
72	Deep-water Cold Seeps, Sedimentary Environments and Ecosystems of the Black and Tyrrhenian Seas and the Gulf of Cadiz (15th training-through-research cruise, June–August 2005). 2007	E only
73	Implementation Plan for the Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS), 2007–2011. 2007 *(electronic only)*	E only
74	Bruun Memorial Lectures, 2005: The Ecology and Oceanography of Harmful Algal Blooms – Multidisciplinary approaches to research and management. 2007	E only
75	National Ocean Policy. The Basic Texts from: Australia, Brazil, Canada, China, Colombia, Japan, Norway, Portugal, Russian Federation, United States of America. (Also Law of Sea Dossier 1). 2008	E only
76	Deep-water Depositional Systems and Cold Seeps of the Western Mediterranean, Gulf of Cadiz and Norwegian Continental margins (16th training-through-research cruise, May–July 2006). 2008	E only
77	Indian Ocean Tsunami Warning and Mitigation System (IOTWS) – 12 September 2007 Indian Ocean Tsunami Event. Post-Event Assessment of IOTWS Performance. 2008	E only
78	Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) – Implementation Plan 2013–2017 (Version 2.0). 2013	E only

(continued)

No.	Title	Languages
79	Filling Gaps in Large Marine Ecosystem Nitrogen Loadings Forecast for 64 LMEs – GEF/LME global project Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems. 2008	E only
80	Models of the World's Large Marine Ecosystems. GEF/LME Global Project Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems. 2008	E only
81	Indian Ocean Tsunami Warning and Mitigation System (IOTWS) – Implementation Plan for Regional Tsunami Watch Providers (RTWP). 2008	E only
82	Exercise Pacific Wave 08 – A Pacific-wide Tsunami Warning and Communication Exercise, 28–30 October 2008. 2008	E only
83.	*Cancelled*	
84.	Global Open Oceans and Deep Seabed (GOODS) Bio-geographic Classification. 2009	E only
85.	Tsunami Glossary	E, F, S
86	Pacific Tsunami Warning System (PTWS) Implementation Plan *(under preparation)*	
87.	Operational Users Guide for the Pacific Tsunami Warning and Mitigation System (PTWS) – Second Edition. 2011	E only
88.	Exercise Indian Ocean Wave 2009 (IOWave09) – An Indian Ocean-wide Tsunami Warning and Communication Exercise – 14 October 2009. 2009	E only
89.	Ship-based Repeat Hydrography: A Strategy for a Sustained Global Programme. 2009	E only
90.	12 January 2010 Haiti Earthquake and Tsunami Event Post-Event Assessment of CARIBE EWS Performance. 2010	E only
91.	Compendium of Definitions and Terminology on Hazards, Disasters, Vulnerability and Risks in a coastal context	*Under preparation*
92.	27 February 2010 Chile Earthquake and Tsunami Event – Post-Event Assessment of PTWS Performance (Pacific Tsunami Warning System). 2010	E only
93.	Exercise CARIBE WAVE 11 / LANTEX 11—A Caribbean Tsunami Warning Exercise, 23 March 2011	
	Vol. 1 Participant Handbook / Exercise CARIBE WAVE 11 —Exercice d'alerte au tsunami dans les Caraïbes, 23 mars 2011. Manuel du participant / Ejercicio Caribe Wave 11. Un ejercicio de alerta de tsunami en el Caribe, 23 de marzo de 2011. Manual del participante. 2010	E/F/S
	Vol. 2 Report. 2011	E only
	Vol. 3 Supplement: Media Reports. 2011	E/F/S
94.	Cold seeps, coral mounds and deep-water depositional systems of the Alboran Sea, Gulf of Cadiz and Norwegian continental margin (17th training-through-research cruise, June–July 2008)	*Under preparation*
95.	International Post-Tsunami Survey for the 25 October 2010 Mentawai, Indonesia Tsunami	*Under preparation*
96.	Pacific Tsunami Warning System (PTWS) 11 March 2011 Off Pacific coast of Tohoku, Japan, Earthquake and Tsunami Event. Post-Event Assessment of PTWS Performance	*Under preparation*
97.	Exercise PACIFIC WAVE 11: A Pacific-wide Tsunami Warning and Communication Exercise, 9–10 November 2011	
	Vol. 1 Exercise Manual. 2011	E only
	Vol. 2 Report. 2013	E only
98.	Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and connected seas. First Enlarged Communication Test Exercise (ECTE1). Exercise Manual and Evaluation Report. 2011	E only

No.	Title	Languages
99.	Exercise INDIAN OCEAN WAVE 2011 – An Indian Ocean-wide Tsunami Warning and Communication Exercise, 12 October 2011 Vol. 1 Exercise Manual. 2011 Supplement: Bulletins from the Regional Tsunami Service Providers Vol. 2 Exercise Report. 2013	E only
100.	Global Sea Level Observing System (GLOSS) Implementation Plan – 2012. 2012	E only
101.	Exercise Caribe Wave/Lantex 13. A Caribbean Tsunami Warning Exercise, 20 March 2013. Volume 1: Participant Handbook. 2012	E only
102.	*(In preparation)*	
103.	Exercise NEAMWAVE 12. A Tsunami Warning and Communication Exercise for the North-eastern Atlantic, the Mediterranean, and Connected Seas Region, 27–28 November 2012, Volume I: Exercise Manual. 2012	E only
104.	Seísmo y tsunami del 27 de agosto de 2012 en la costa del Pacífico frente a El Salvador, y seísmo del 5 de septiembre de 2012 en la costa del Pacífico frente a Costa Rica. Evaluación subsiguiente sobre el funcionamiento del Sistema de Alerta contra los Tsunamis y Atenuación de sus Efectos en el Pacífico. 2012	Español solamente (resumen en inglés y francés)
105.	Users Guide for the Pacific Tsunami Warning Center Enhanced Products for the Pacific Tsunami Warning System. 2013	E, S
106.	Exercise Pacific Wave 13. A Pacific-wide Tsunami Warning and Enhanced Products Exercise, 1–14 May 2013. Vol. 1 Exercise Manual. 2013	E only
107.	Tsunami Public Awareness and Educations Strategy for the Caribbean and Adjacent Regions. 2013	E only