BASIC INFORMATION

1. ICG/CARIBE EWS Tsunami National Contact

Tsunami National Contact (TNC)

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2. ICG/CARIBE EWS Tsunami Warning Focal Point

Tsunami Warning Focal Point (TWFP) - Puerto Rico

Puerto Rico State Emergency Management Agency
PO BOX 00906-6597
San Juan, Puerto Rico 00906-6597
Tsunami Warning Focal Point (TWFP) Alternates - Puerto Rico

DOC/NOAA/National Weather Service Forecast Office
Nº 4000 Road 190
Carolina, Puerto Rico  00979 USA

Tsunami Warning Focal Point (TWFP) - Virgin Islands

Virgin Islands Territorial Emergency Management Agency
7 & 8 King Cross Street
Christiansted, VI 00820

National Tsunami Warning Centers

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3. Tsunami Advisor

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4. Local Tsunami Procedures (if a local tsunami hazard exists)

A local tsunami is a tsunami that is generated from a nearby source, generally less than 200 km away. The source can be an earthquake, landslide or a volcanic eruption. The waves can arrive onshore within minutes of the triggering event.

The responsibility for issuing tsunami warning information to the Caribbean is currently shared by the Pacific Tsunami Warning Center (PTWC) and the West Coast/Alaska Tsunami Warning Center (WC/ATWC). The Area of Responsibility (AOR) of the WC/ATWC includes the East Coast and Gulf of Mexico of the US, Eastern Canada and in the interim includes Puerto Rico and the Virgin Islands. PTWC covers the rest of the Caribbean and Western Atlantic (Figure 1).

![Tsunami Warning Centers Areas of Responsibility](image)

Figure 1. Areas of responsibility of the WC/ATWC and PTWC in the Caribbean.

The Centers detect, locate, size, and analyze earthquakes throughout the world. Earthquakes that activate the Centers’ alarm system initiate an earthquake and tsunami investigation which includes the following four basic steps: automatic locating and characterizing the earthquake; earthquake analysis and review; sea level data analysis and tsunami forecasting; and disseminating the information through various means.

Products issued by the WC/ATWC for its AOR are warning, advisory, watch, and information statement. Each has a distinct meaning relating to local emergency response. In summary:

<table>
<thead>
<tr>
<th>NOTIFICATION LEVEL</th>
<th>STATUS</th>
<th>SUGGESTED ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>Inundating wave possible</td>
<td>Full Evacuation Suggested</td>
</tr>
<tr>
<td>Advisory</td>
<td>Strong Currents Likely</td>
<td>Stay away from the shore</td>
</tr>
<tr>
<td>Watch</td>
<td>Danger level not yet known</td>
<td>Stay alert for more info</td>
</tr>
<tr>
<td>Information</td>
<td>Minor waves at most</td>
<td>No action suggested</td>
</tr>
</tbody>
</table>
Based on seismic data analysis or forecasted amplitude (dependent on whether the Center has obtained sea level data); WC/ATWC will issue the appropriate product.

- Warnings and Advisories suggest that action be taken.
- Watches are issued to provide an early alert for areas that are distant from the wave front, but may have danger. Once the danger level is determined, the watch is upgraded to a warning or advisory, or canceled.
- A tsunami Information Statement is issued to inform emergency management officials and the public that an earthquake has occurred, or that a tsunami warning, watch or advisory has been issued for another section of the ocean. In most cases, information statements are issued to indicate there is no threat of a destructive basin wide tsunami and to prevent unnecessary evacuations as the earthquake may have been felt in coastal areas. An information statement may, in appropriate situations, caution about the possibility of destructive local tsunamis.

Figure 2 outlines the criteria for issuing the different products.

For local earthquakes either a tsunami warning or an information statement is issued. For regional and teleseismic events, advisory and watch statements might also be issued.

![Figure 2. Procedure chart for West Coast Alaska Tsunami Warning Center. At the top is the source zone of the earthquake, below the area of impact, if different from source zone. If deeper than 100k and <7.9, a TIS is issued.](image)

Tsunami messages (warnings, advisories, watches, and information statements) issued by the TWCs are disseminated by a variety of means including telephone, dedicated text circuits such as Global Telecommunications System (GTS), Emergency Managers Weather Information Network (EMWIN), Aeronautical Fixed Telecommunications Network (AFTN), National Warning System (NAWAS) and Advanced Weather Interactive Processing System (AWIPS), email, and fax to the officially designated responsible government agencies (Tsunami Warning...
Focal Points) in each jurisdiction. The Puerto Rico State Emergency Management Agency and the Virgin Islands Territorial Emergency Management Agency as Tsunami Warning Focal Points, carry out their procedures for alerting the public (with interoperability systems, sirens or by other means), and for alerting the responding agencies such as the police, fire departments, and rescue units and media outlets. The National Weather Service San Juan Forecast Office activates the Emergency Alert System (EAS) for Puerto Rico and the US Virgin Islands to interrupt commercial radio and television with a message, and by broadcasting tsunami information over the NOAA All-Hazards Weather Radio (NWR). The multiple ways for the Tsunami Warning Center to disseminate the messages are presented in Figure 3.

![Figure 3. Tsunami message communications.](image)

The Puerto Rico Seismic Network (PRSN) also issues tsunami alerts for Puerto Rico and the Virgin Islands using the same criteria as the WCATWC, with whom they collaborate closely. The PTWC has interim responsibility for issuing tsunami information and watch bulletins for the wider Caribbean outside of Puerto Rico and the Virgin Islands. International responsibilities are by agreement and in coordination with UNESCO/IOC tsunami programs. The Pacific Tsunami Warning Center is also the back-up to the WC/ATWC.

The TWCs will monitor a local tsunami using all available means which includes seismic data, information from sea level gauges and buoys, information from the media, and reports received by telephone from the public or through government agencies. Based on these data and when it is determined that the threat has passed, the tsunami warning/watch/advisory will be canceled by the TWCs. A TWC cancellation, however, does not mean it is safe to return to evacuated areas. This determination must be made by local authorities based upon local information about any continuing wave conditions and other hazards that may be present such as fires or downed power lines. It is these local conditions that make it essential for pre-coordination.
amongst key organizations within each nation responsible for coordination during a warning and emergency response to a tsunami event.

For local events, the populations and government agencies are being educated to immediately run for higher ground or to the upper stories of a building in the case of very hard ground shaking. Government agencies are being trained to activate immediately their response plans. It is probable that warning information may not come in time in near shore local events. People must understand their local risks.

5. **Distant Tsunami Procedures (when distant tsunami hazard exists)**

Both PTWC and WC/ATWC monitor the entire Caribbean/Atlantic region for large earthquakes that may cause a destructive distant tsunami. The WC/ATWC has interim primary responsibility for preparation and dissemination of tsunami warning, advisory, watch, and information products for tsunami events that occur north of 23 degrees N latitude, in the Gulf of Mexico, and near Puerto Rico and the Virgin Islands. PTWC has interim primary responsibility for preparation and dissemination of tsunami watch statements for tsunami events that occur elsewhere in the Atlantic/Caribbean. Each Center monitors data from relevant observing stations of the Atlantic-wide network of coastal and deep-ocean sea level stations as the tsunami propagates outward from the source and passes each gauge. Based on the sea level data, forecast model outputs constrained by the sea level data, and any other warnings, watches, or advisories will be continued, upgraded or canceled.

Similar to the procedures described above for local tsunamis, distant tsunami warnings issued by PTWC and WC/ATWC are disseminated by a variety of means including telephone, dedicated circuits, email, and fax to the responsible government agencies in each jurisdiction that may, depending upon the local laws and policy, be the country, state, county, or municipality. The responsible agencies then carry out their procedures for alerting the public (with sirens or by other means) and for alerting the responding agencies such as the police, fire departments, and rescue units. TWC warnings are also simultaneously sent to Weather Forecast Offices (WFOs) that assist with the public dissemination and local interpretation by activating the EAS to interrupt commercial radio and television with a message, and by broadcasting tsunami information over the NWR. Tsunami messages may also be received and subsequently interpreted and re-disseminated by the media.

The WC/ATWC collaborates closely with the Puerto Rico Seismic Network (PRSN) for earthquakes and potential tsunamis in the region. The PRSN also provides guidance to the Emergency Management Agencies in Puerto Rico and the U.S. and British Virgin Islands, and the media and WFO San Juan as well as the Dominican Republic met office (ONAMET).

PTWC and WC/ATWC will monitor a distant tsunami using all available means including data from seismic stations, sea level gauges, information from the media, and reports received by telephone from the public or through government agencies. Based on these data and when it is determined that the threat has passed, the tsunami watch/warning/advisory will be canceled. A TWC cancellation, however, does not mean it is safe to return to evacuated areas. This determination, known as “all clear”, must be made by local authorities based upon local information about any continuing wave conditions and other hazards that may be present such as fires or downed power lines.
6. Sea Level Network

The United States supports an extensive sea level network in the Pacific, Atlantic and the Caribbean. In Puerto Rico and the U.S. Virgin Islands data is used for a variety of purposes including climate change, and tsunami detection and measurement. Gauges are operated by PTWC, WCATWC, National Ocean Service (NOS), National Data Buoy Center (NDBC), PRSN, the University of Hawaii Sea Level Center (UHSLC), nations in the region, and internationally under the auspices of the Global Sea Level Observing Program (GLOSS). These stations are included in the map of sea level stations in the Caribbean (Figure 4). A brief synopsis of the various gauges follows:

• **National Ocean Service (NOS).** NOS’s Center for Operational Oceanographic Products and Services (CO-OPS) operates most of the U.S. coastal stations including 210 long-term stations comprising the National Water Level Observation Network (NWLO). These multi-purpose gauges each have, at a minimum, a primary and backup sensor and data collection platform. High-frequency 1-minute water level data are collected and transmitted every 6 minutes over one of the two U.S. meteorological satellites (GOES-E or GOES-W), telephone, IP modem, or Iridium. Data are also sent to the TWCs. In addition to the eleven NWLO stations located in Puerto Rico and the U.S. Virgin Islands, NOS also operates a real-time station in Bermuda and completed installation of a long-term, multi-hazard Barbuda in 2011 in support of the Caribbean Sea Level network.

• **University of Hawaii Sea Level Center (UHSLC).** A number of coastal gauges in the Pacific are operated for IOC’s Global Sea Level Network (GLOSS) by the UHSLC. UHSLC gauges have a primary and backup sensor, and are typically operated for a specific application. Most gauges sample at 1 sample per minute with data sent over either a GOES satellite or the Japan meteorological satellite (GMS) with a transmission interval of either 5 or 15 minutes. With financial support from NWS and with the PRSN, the UHSLC has upgraded/installed four tsunami ready stations in the Caribbean (Costa Rica, Dominican Republic (2) and Curacao. Two additional stations were installed in Dominica and Grenada. Four additional stations are to be deployed in the Caribbean basin by 2013 in Colombia (2), Turks and Caicos and Panama. All these stations transmit every 5 minutes and also meet GLOSS standards for sea level observations and are currently providing data to appropriate Warning Centers and Weather Service Offices.

• **National Data Buoy Center (NDBC).** The U.S. operates 32 tsunami stations in the Pacific Ocean and seven in the Atlantic, Gulf of Mexico, and the Caribbean Sea. The tsunami stations employ the second-generation Deep-ocean Assessment and Reporting of Tsunamis (DART® II) technology. The technology uses a recorder on the seafloor that samples the pressure at 15-s intervals and communicates with a surface buoy. The technology has two-way communication between the TWCs or NDBC and the pressure recorder on the seafloor. These tsunami stations have a standard mode that communicates every 6 hours with a 15-minute subsampling of the full 15-s sampling intervals. All tsunami stations have a triggered mode that replaces the standard mode. The triggering can be initiated by either the tsunami detection algorithm embedded with the seafloor recorder or externally using the two-way communications. The triggered mode provides a few minutes of the 15-s full resolution data and then approximately three hours of one-minute averages that are sent every few minutes. The tsunami station will return to standard mode of operations after three hours of triggered mode unless re-triggered. NDBC receives the data from the tsunami stations and reformats the data into messages for distribution on the GTS and NOAAPORT under the GTS bulletin header SZNT01 KWNB for the Atlantic, Caribbean, and Gulf of Mexico tsunami stations. NDBC also posts the data to its website. NDBC’s Data Assembly Center
(DAC) continuously monitors the tsunameters and validates triggers with the cognizant TWC. Data from these stations are critical for constraining tsunami forecast models.

- The Puerto Rico Seismic Network (PRSN) of the University of Puerto Rico at Mayagüez (UPRM) operates 6 sea level stations in Puerto Rico. The 6 tide gauge stations are NOS compliant and were funded by FEMA and the UPRM and installed and with the support and guidance of NOS between 2006 and 2008. All of these stations also meet GLOSS standards for sea level observations and are currently providing data to appropriate Warning Centers and Weather Service Offices. The data are transmitted every 6 minutes on GOES. The data can be accessed on the home page of the PRSN, Tides and Currents site of NOAA, and Tides on Line site of NOAA. With funds provided by the US, the PRSN also installed and provides support for the operation of a sea level station in Puerto Caucedo, east of Santo Domingo, in the Dominican Republic which transmits every 5 minutes. By the end of 2012, a new station will be installed in Barahona province of the Dominican Republic and the sea level station in Tortola will be upgraded. With a joint project, PRSN and UNESCO installed a tide gauge station in Haiti (Cape Haitian).

- Ten sea level gauges were installed as part of the Project Mainstreaming Adaptation to Climate Change (MACC) of the Caribbean Community Center for Climate Change. Each of the stations were equipped with an Aquatrak water level sensor and a met package. NESDIS provided 1 hour transmission slots for these stations located in Guyana, Barbados, Dominica, Grenada, Saint Vincent and the Grenadines, St. Kitts and Nevis, St. Lucia, Jamaica, Belize and Bahamas. These stations are now under the responsibility of each of the countries. Of these stations, only the Barbados, Bahamas and the Jamaica stations are operational, although they do not meet Tsunami standards. Of the remaining stations, two completely new stations were installed at Dominica and Grenada as part of the UHSLC project. The stations were evaluated by the PRSN as part of an IOC project to install new stations in the Caribbean. The station in Barbados was going to be upgraded with ICSECA funding. Additional funding will need to be identified to complete the repairs and upgrades of the remaining stations.

- The following link of the Caribbean Tsunami Warning Program provides a connection to an interactive map of all the existing, planned, required sea level stations in the Caribbean:
  

- The following link of the provides a connection to the IOC Sea Level Monitoring Facility with an interactive map of most of the sea level stations operational in the Caribbean with remote communication systems (GOES, FTP, etc.):
  

- The followings links provides a connection to a interactive map (with time series) of the tide stations in the NOS system:
  

- The following link provides a map of the tsunameter (DART) stations:
  
7. Seismic Network

The United States supports an extensive seismic network in the Pacific, Atlantic and the Caribbean regions. These stations are a part of the Global Seismographic Network (GSN) and operated by the U.S. Geological Survey (USGS), University of San Diego (IDA stations), and regional networks including the Puerto Rico Seismic Network (PRSN). Figure 5 below shows the locations of these stations plus the stations from regional seismic network currently sending data in real time. Data for all the US stations and many other regional networks are freely available in real time through the IRIS Data Management Center and/or the PRSN. Some seismic stations are equipped with strong motion sensors and GPS.

In the past year, the USGS installed 5 strong motion sensors in Haiti for the purpose of studying local site amplification due to earthquake shaking in Port-au-Prince. While the TWCs do not currently use triggered strong motion data, this might be a direction of future development in order to improve the general monitoring capability of the CORE seismic network. This is especially important given the recent degradation of monitoring capabilities in the Hispaniola Island region due to the loss of real-time seismic stations operated by the Canadian government,

![Figure 4. Map of sea level gauges in the Caribbean as of March, 2012.](image)

- The following link provides a list of the Tide Stations of the NOS: [http://co-ops.nos.noaa.gov/station_retrieve.shtml?type=Tide+Data](http://co-ops.nos.noaa.gov/station_retrieve.shtml?type=Tide+Data)
- The following link provides information on the sea level stations operated by the PRSN or regional stations received via GOES [http://redsismica.uprm.edu](http://redsismica.uprm.edu)
PRSN and the Dominican Republic. The loss of real-time data, from the Hispaniola region, to the TWCs has resulted in a moderate degradation in the magnitude detection threshold (0.3-0.4 magnitude units) and earthquake location precision and a significant increase in the detection time of earthquake by the core network (10-25secs). In order to maintain a high-quality monitoring network, The US should encourage and support the Haitian and Dominican Republic governments in adopting equipment from contributing nations (Canada, US).

http://earthquake.usgs.gov/monitoring/gsn/

http://earthquake.usgs.gov/monitoring/anss/regions/pr/

http://redsismica.uprm.edu

http://www.iris.edu/gmap/_CARIBE-EWS

8. GPS

Global Positioning Systems (GPS) are now being integrated into tsunami warning systems. They can be used to characterize the size of large earthquakes in the region. Also when collocated with tide gauges, the data are used to constrain these datum.

The Puerto Rico Seismic Network also operates a GPS Network which was funded by the NSF Major Research Instrumentation Program (EAR-0722540, August 1, 2007-July 31, 2009). It currently consists of 9 high rate continuously transmitting stations. One of its primary objectives is to provide additional information to help size and characterize very large earthquakes in the region. All of the permanent GPS stations are equipped with a Trimble NetRs GPS receiver or TopCon and Choke ring antenna. Continuous data are simultaneously
logged to three sessions with different sampling rate, 15-sec per sample, 1-sec per sample (1 Hz), and 10-samples per second (10 Hz). The 15-sec interval session is designed for traditional plate motion study purpose. The 1-Hz session is designed for both earthquake study and RTK surveying purposes. The 10-Hz session is specially designed for recording seismic waves. Daily 15-sec interval data and hourly 1-sec interval data are automatically downloaded to the PRSN and the UNAVCO Data Archiving (http://facility.unavco.org/data/data.html). While 10-Hz data will be downloaded only when necessary, in response to specific triggering events such as a large earthquake, volcanic crisis, traveling ionospheric disturbance, or specialized survey. These high-rate data (10 Hz) can be stored on the receiver as long as 8 days.

In 2010 the National Science Foundation funded the Continuously Operating Caribbean GPS Observational Network (COCONet). COCONet will be installing 50 new continuous Global Navigation Satellite System (cGNSS) and meteorology stations in the Caribbean and Central America, refurbish an additional 15 stations, and archive data from 62 cGNSS stations (managed by various institutions committed to free and open data access) that are already or will soon be in operation (Figure 7). This project will infuse and complement existing large-scale, state of the art geodetic and meteorological infrastructure in the Caribbean, forming the backbone for a broad range of Earth and atmospheric science investigations and enabling research on process-oriented science questions with direct relevance to geohazards. The observational infrastructure will serve as a regional platform for more focused topical geophysics studies by members of an international community of scientists. Although the main purpose of the GPS is for tectonic and weather research, there is interest in using the data in real time tsunami and earthquake information and warning systems. The infrastructure will also serve as a platform for international partnerships for science and societal applications. As part of this project, the plan is to install 50 GPS stations in the Caribbean and integrate 50 existing GPS stations. Two meetings of US and Caribbean stakeholders and researchers were held in 2011 (http://www.agu.org/journals/ce/v093/i009/2012EO090001/2012EO090001_brr.pdf)

The National Geodetic Survey (NGS) also have five GPS stations installed in Puerto Rico, the Virgin Islands, Bermuda and Barbados.
9. **Information on Tsunami occurrences in 2011-2012**

During the inter-sessional period no tsunami warning, advisories or watches were issued for the region. The WC/ATWC issued dozens of informational statements for Puerto Rico and the Virgin Islands for events of M>4.0 within the PR/VI AOR and greater than 6.0 in the Atlantic (South Sandwich Islands, in particular). Several earthquake events across the region were large enough to be felt by the public and because of the attention from these events, numerous inquiries were made to WFO San Juan, PRSN, PTWC and the WC/ATWC. In Puerto Rico, in May 16, December 24, 2010 and Dec 17, 2011 earthquakes were felt strong enough that, although there was no tsunami threat, some citizens evacuated the low lying areas. For these events, the tsunami products issued by the PRSN and WC/ATWC were used to inform the public that there was NO tsunami threat.

10. **Web sites (URLs) of national tsunami-related web sites**

U.S. Tsunami Website –  
http://www.tsunami.gov

Caribbean Tsunami Warning Program  
http://www.srh.noaa.gov/srh/ctwp

Pacific Tsunami Warning Center –  
http://www.prh.noaa.gov/ptwc

West Coast and Alaska Tsunami Warning Center –  

http://wcatwc.arh.noaa.gov
International Tsunami Information Center –
http://www.tsunamiwave.info
National Data Buoy Center (tsunameter information) –
http://www.ndbc.noaa.gov/dart.shtml

National Geophysical Data Center website:
http://www.ngdc.noaa.gov/hazard/hazards.shtml
National Geophysical Data Center (historical tsunamis) –
Pacific Marine Environmental Laboratory (tsunami research) –
http://nctr.pmel.noaa.gov
National Ocean Service (U.S. coastal sea level data) –
http://tidesandcurrents.noaa.gov/tsunami
University of Hawaii Sea Level Center (GLOSS global sea level data) –
http://illikai.soest.hawaii.edu/RSL/
U.S. Geological Survey (earthquake information) –
http://earthquake.usgs.gov/eqcenter/
TsunamiReady website –
http://www.tsunamiready.noaa.gov/
NOAA/NGS/Remote Sensing Division - Digital Aerial Imagery of Haiti post event:
Puerto Rico Seismic Network
http://redsismica.uprm.edu

10A. Summary recent tsunami warning and mitigation system improvements

- **TsunamiReady.**
  - 8 new TsunamiReady™ communities were added to Puerto Rico since the last meeting: Quebradillas, Toa Baja, Yauco, Guayanilla, Peñuelas, Juana Diaz, Guayama, and Arroyo. Puerto Rico now has 20 TsunamiReady communities; these represent 45% of the tsunami threatened communities in the Commonwealth. Work is underway in 9 additional communities to meet the TR requirements by July, 2012.
  - The USVI has made significant advances towards meeting TsunamiReady requirements. In January, 2012, Governor de Jongh signed the Tsunami Response Plan. In addition 10 siren systems have been installed, new 24 hr state of technology facilities that serve as the USVI tsunami warning points
were inaugurated, tsunami signage has been procured and community education and training exercises have been conducted.

- In November, 2011, Anguilla was recognized as the first international TsunamiReady community. The recognition ceremony was held December 6, 2011

- **Caribbean Tsunami Warning Center.** The U.S. has adopted a phased strategy in developing a Caribbean Tsunami Warning Center. These phases are *planning* phases, not *implementation* phases. The results and timing of each phase will determine next steps, including decisions about whether or not to continue the planning process. The three phases are:
  1) Enhance tsunami outreach and education capacity in the Caribbean;
  2) Strengthen Caribbean Regional Tsunami monitoring systems; and
  3) Establish a Regional Tsunami Warning Center at the University of Puerto Rico Mayaguez.

- **Caribbean Tsunami Warning Program.** On February 1, 2010 NWS established the Caribbean Tsunami Warning Program (http://www.srh.noaa.gov/srh/ctwp), co-located with the Puerto Rico Seismic Network at the University of Puerto Rico in Mayagüez. Currently it is staffed by the Manager and one Student. Plans are underway to hire additional personnel when budget conditions permit in 2012. This is the first step of the U.S. phased deployment of a Caribbean Tsunami Warning Center. The CTWP works with local, national and international stakeholders and partner to improve tsunami monitoring (Sea Level, Seismic and GPS), warning (existing and new warning and forecast models), communications and education and preparedness efforts, including the TsunamiReady program. Below are some of the activities that were carried out by the CTWP during the intersessional period (May 2011- March 2012) in support of CARIBE EWS.

  - **Staffing.** The CTWP is currently staffed by the Manager and one Student. Plans are underway to hire an additional student and scientist.
  - **Facilities.** The UPRM concluded the remodeling of an additional facility that the CTWP will be occupying in proximity to the PRSN and in addition to the space within the PRSN it uses as an operations center.
  - **Tsunami Warning and Forecasting.** CTWP is collaborating with the PMEL for the development, validation and implementation of an Internet Tsunami Forecasting System. It also is working with the US TWC and the US TWP in the evaluation of products issued by the tsunami warning centers.
  - **Communications.** In addition to its website (http://www.srh.noaa.gov/srh/ctwp), the CTWP also maintains a Facebook Fan Page.
  - **Seismic Data.** The CTWP provided monthly reports on Seismic Data Availability for the stations contributing to PRSN and IRIS under CARIBE EWS,
  - **Sea Level Data.** CTWP maintains a data base on sea level stations in the Caribbean and Western Atlantic, as well as the Interactive Sea Level Stations Google Map on its website. CTWP presented a status report on the CARIBE EWS sea level network at the GLOSS Group of Experts Meeting in November
2011. CTWP is also supporting the installation of tsunami capable sea level station in Barbados.

- **GPS.** CTWP maintains communications with the US NSF COCO Net (Caribbean GPS Network) project team in support of GPS applications for sea level monitoring and tsunami warning operations.

- **Funding.** The CTWP was awarded $70,000 for the NWS VCP Project *Enhancing Multipurpose Sea Level Monitoring and Forecasting Capabilities in the Caribbean and Adjacent Regions* to be carried out in 2012-2013.

- **Training.** The CTWP participated in the Seismic Network Operators short course and is helping with the organization of the third sea level workshop in Mexico in June, 2012.

- **Education and Outreach.** The CTWP participated in education and outreach efforts in Puerto Rico, USVI, Anguilla and the US mainland. New education and outreach materials were also developed. The CTWP gave a plenary talk at the Annual Meeting of the Caribbean Shipping Association in October, 2011 (500 participants) and submitted an article on Tsunamis in the Caribbean, which was published by the CSA in their journal, Caribbean Maritime (http://issuu.com/landmarine/docs/cm13) and has been included in digital libraries of institutions, like the University of Florida (http://ufdc.ufl.edu/UF00099408/00015). CTWP also has provided input for the business and work plan of the CTIC.

- **Tsunami Ready.** In 2011 it worked with stakeholders in Puerto Rico for the recognition of an additional 8 TsunamiReady communities in Puerto Rico. CTWP also developed the framework for a joint UNESCO – NWS TsunamiReady recognition. In December 2011, Anguilla was recognized in an official ceremony as the first-ever International TsunamiReady community.

- **Exercises.** The CTWP submitted to the Technical Secretary the draft report of CARIBE WAVE 11. It supported the LANTEX 12 exercise, as well as developing a proposal for the CARIBE WAVE 2013 to be considered by the ICG VII.

**Tsunami Communication Tests in the Caribbean.** In accordance with what was agreed to at the sixth meeting of the ICG/CARIBE-EWS, PTWC conducted monthly communication tests to all of the CARIBE-EWS designated Tsunami Warning Focal Points on the first Thursday of each month at 1530 UTC, beginning in October 2011. The scheduled test of February 2, 2012 was cancelled due to PTWC handling a small tsunami in the Pacific at the same time. A few communication problems have been reported and addressed in response to these tests. Also in accordance with what was agreed, PTWC conducted two unscheduled “no notice” communication tests, one on February 4, 2012 and another on March 25, 2012. In the first of those tests, the message was inadvertently sent to a much wider distribution than intended including the IOC Public Tsunami List, the Tsunami Bulletin Board, and to ships at sea. This resulted in a flood of unintended responses. The second unscheduled test was sent to the normal distribution. Results are still being compiled and will be reported to the ICG.

**Paleo Tsunami research.** The USGS has funded research in both the USVI and the BVI to detect prehistorical tsunami events. In February/March field studies were conducted in both of these territories.
o British Virgin Islands. A group of scientists from USGS, NOAA, the University of Puerto Rico at Mayagüez and Institut Physique du Globe de Paris (IPGP) and consultant Martitia Tuttle made progress in identifying several tsunami events on the island of Anegada. The most recent event was dated in the 1650-1800 range (1755 Lisbon event?), an earlier event in the 1200-1450 range and a third event which has still not been dated. Local, regional and teleseismic events are being evaluated as sources.

o UPR Graduate Student, Zamara Fuentes and Consultant Martitia Tuttle with the field support of Dr. Roy Watlington of the USVI conducted a reconnaissance trip in St. Thomas and offshore islands. The initial findings point towards two or more overwash deposits, including shelly sand and large corals, in several salt ponds. They hope to return to St. Thomas.

o UPR Scientist and Martitia Tuttle (Consultant) have also been conducting and planning additional reconnaissance in northeastern Puerto Rico and nearby islands.

- **USGS Caribbean activities.**

  o **Haiti Seismic Network – Sue Hough**

    Five netquakes strong motion sensors have been deployed in Haiti (4 in the Port-au-Prince) installed in May-June 2011, with funding support from USAID/OFDA through the USGS-USAID Earthquake Disaster Assistance Program Participating Agency Service Agreement.

    Computer for data center setup at BMG.


    NEIC receives data triggers in realtime.

  o **UNESCO-IOC ICSECA funded project:**

    Interagency Research Project between the USGS and NOAA:

    Detection of tsunami using existing island based seismic stations in the Caribbean.

    Daniel E. McNamara USGS National Earthquake Information Center
    Christa Von Hillebrandt NWS CTWP
    Lind Gee USGS Albuquerque Seismological Laboratory
    Jean Weaver USGS International Programs

- **Tsunami Modeling Training.** A ComMIT training course sponsored by UNESCO’s Intergovernmental Oceanographic Commission (IOC) was held in Guadeloupe on October 24-28, 2011. ComMIT is an interface for NOAA’s propagation/inundation tsunami code, MOST, and the training was provided by personnel of the NOAA Center for Tsunami Research. The 5-day course included the preparation and pre-processing of the computational grids (three) and how to use the MOST code to prepare inundation maps based using pre-computed sources in the Caribbean region. Trainees were from Aruba, Antigua & Barbuda, Bahamas, Barbados, Cuba, Dominican Republic, El Salvador, Haiti, Panama, Trinidad and Tobago.

- **Tsunami Forecasting.** NOAA Pacific Marine Environmental Laboratory is developing iTFS. This application exposes two web-based clients. The forecast client
exposes the full tsunami forecasting user-interface with functionality to generate propagation forecast, do inversions, and run flooding forecast where these are available. This client also allows a privileged user to selectively expose model results to the second iTFS client. The second iTFS client, is a view-only client with no forecast capabilities, but allows users to view only the results selected to be exposed by the forecast user. View-only client development is mostly complete, while the forecast client capabilities are being implemented as we build the intermediate software tiers between the web infrastructure and the SIFT software back-end. While the layout implementation of the forecast client is complete, development is now focused on the web-based iTFS inversion capability and functionality. These web-based clients are served from a three tier server implementation of which development is progressing well. The first version of the SIFT to iTFS tier is complete, and all application tier housekeeping, user management and user authentication functionality is complete. The user-authenticated iTFS functionality outside the PMEL firewall will be exposed as soon as we can. Internal testing of the iTFS though a new network device that adds application and network security. The CARIBE EWS will be integrated into the testing and be able to provide feedback.

- **EMWIN.** The U.S. conducted a regional training on and deployment of the Emergency Managers Weather Information Network (EMWIN) in the Caribbean and Central America, held in Puerto Rico in February 2011 and another workshop in May 2011 in Aruba. Funding for this activity was provided by the US Agency for International Development (USAID) Office of US Foreign Disaster Assistance (OFDA) through a Participating Agency Service Agreement (PASA) with the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS). This activity was implemented by the International Extension and Public Alert System (IEPAS) / RANET program at the University Corporation for Atmospheric Research (UCAR) Joint Office of Science Support (JOSS) in close coordination with the NWS and NWS EMWIN team. Thru this initiative 37 EMWIN stations have been deployed throughout the region at National Meteorological Hydrological Services (NMHSs), emergency management entities, and related agents. The activity also greatly increased the training and support materials for the EMWIN system; particularly those serving the international user community. In Puerto Rico, as part of the TsunamiReady program another 20 stations are being deployed for a total of almost 60 EMWIN stations in the region.

GOES-12 was replaced by GOES-13 in mid April, 2010. With the new satellite Emergency Management Information Network (EMWIN) and Data Collection Platform (DCP) collection will remain largely the same, however many older EMWIN receivers will need to be upgraded by the users. Some of these needs were covered with the PASA Project above, but there still may be systems that need upgrade support.

- **CARIBE EWS Video.** The USGS, with funding from NOAA and technical guidance from the CTWP released a video on the Caribbean Tsunami Warning System in 2011.

- **Caribbean Tsunami Information Center.** NOAA contributed resources to the Caribbean Tsunami Information Center (CTIC) in last 2 years:
The International Tsunami Information Center (ITIC) and Caribbean Tsunami Warning Program (CTWP) have both supported requests for tsunami materials from countries in the region.

ITIC is providing its stock of materials to the CTIC for its use and distribution to Member States. In 2011, more than 5000 copies were sent to 6 countries and the ICG/CARIBE-EWS-VI session. Materials available include Tsunami, Great Waves; Tsunami Glossary; Surviving Tsunamis, Lessons Learning from Chile, Hawaii, and Japan (1960 Chile tsunami, USGS Circular 1187); Where the First Wave Arrives in Minutes (2004, 2006 Indonesia tsunamis); Posters (Global Tsunami Sources through 2011, Tsunamis on the Move, Sensing a Tsunami), etc.

ITIC-Chile will be translating and printing materials in Spanish in 2012, and these will be available to CTIC and directly to Member States.

- **International Tsunami Information Center.** The UNESCO/IOC – NOAA International Tsunami Information Center reports on the following international capacity building activities:
  
  - Conducted its annual ITIC Training Programme – Hawaii (ITP-Hawaii) on tsunamis and tsunami warning systems 22 August – 2 September 2011. Altogether, there were 15 participants from 12 PTWS and CARIBE-EWS countries, including the Director of the Antigua and Barbuda Meteorological Services and Technical Staff from the Service Maritime et de Navigation D’Haiti (SEMANAH). USAID/OFDA supported 1 Caribbean participant to the ITP (in addition to 2 from the South-east Pacific) last year, 2011. The ITP-Hawaii 2010 was attended by 19 persons from nine countries, including the Director of the Saint Lucia Emergency Management Organization. In the past, staff from Nicaragua INETER and Colombia CCO and OSSO have attended.
  
  - Developed a 1-day Tsunami Awareness course targeting agencies with response responsibility. This awareness-level course provides a basic understanding of tsunamis, hazard assessment, warning and dissemination, and community response strategies to effectively reduce tsunami risk. No advanced knowledge and experience of tsunamis is required. The goal of the course is to enhance participants’ abilities to support their agency's preparedness and response efforts. The international course was modeled after a 1-day certified course (AWR-217) developed by ITIC for the US DHS FEMA National Disaster Preparedness Training Center, and was used in Tonga and Fiji in 2010 (flyer attached as Annex).
  
  - Course materials for both courses above are posted online as part of the IODE OceanTeacher Academy at [http://classroom.oceanteacher.org](http://classroom.oceanteacher.org)

- **COMET online training modules.** Three online training modules were completed/updated since the last sessional: Tsunami Community Preparedness, TsunamiStrike!, and TsunamiStrike! for the Caribbean. The Tsunami Strike! Caribbean Edition offers an interactive learning experience in which learners take on the role of a journalist writing an article for a news magazine. Although developed thinking of Intermediate and High School students, it is also a great tool for all to learn more about tsunamis in the Caribbean.
• **Working Group Meetings**
  
  o WG I. Dan McNamara and Christa von Hillebrandt attended the WGI meeting in Puerto Rico in August 2011.
  
  o WGIV. Julie Leonard attended WGV highlights in February in Barbados, which provided input on the work plan for the interim and permanent CTIC.
  
• **The Puerto Rico Seismic Network has provided support to the region:**
  
  o Installed a new seismic station in Aruba. Support to the Haiti seismic and tsunami program via a cooperation research project with UNESCO. As part of this project it installed a sea level station in northern Haiti.
  
  o Helping to deploy and maintain 10 tide gauges stations in the Caribbean through the UH PRSN collaborative project: Dominica and Grenada stations were installed in May 2011.
  
  o Provides support to the Seismological Institute of the Dominican Republic (ISU)
  
  o Provides maintenance of one sea level station and is providing equipment and support to Dominican Republic for an additional station in southwestern Dominican Republic, Barahona.
  
  o Organized a seismic network operator’s short course in Mayaguez, Puerto Rico, August 2011.
  
  o A short training on EarlyBird, with participation from Mexico, Nicaragua, Colombia and Venezuela was held in August 2011.
  
  o Technical groups were received in the Puerto Rico Seismic Network from Haiti and Jamaica.
  
  o PRSN develops a tide gauge web base tool kit to evaluate the tide gauge data availability.
  
  o PRSN with support from UNESCO visited 5 countries to evaluate sites to install five new tide gauge station in: Nicaragua, Guatemala, Cayman, St Vincent and St. Kitts.
  
**10B. Summary of plans of future tsunami warning and mitigation system improvements**

• LANTEX exercise will be conducted on March 28, 2012. The CTWP and TWC would be the focal points within NOAA/NWS. PMEL could also be approached to support these exercises.

• CTWP will continue to prepare and distribute for CARIBE EWS monthly reports on seismic data availability for tsunami warning purposes (PRSN) and long time archival at IRIS in support of CARIBE EWS WG1.

• The CTWP continues to collaborate with the Tsunami Research Team of NOAA Pacific Marine Environmental Laboratory *Web Enabled Tsunami Forecast Tools* project. The purpose is to present the research and development environment for tsunami warning experts, emergency management practitioners, scientists, and engineers to maintain accurate, standardized tsunami forecasting and, at the same time, to improve the scientific understanding of tsunamis and tsunami-related impacts that would lead to better forecast and warning techniques. The web-based application will
support the CARIBE EWS efforts for improved forecast capabilities based on the latest science as well as operational standards and procedures.

- To enhance sea level data availability for tsunami and other coastal observation and warning systems in the Caribbean, the CTWP:
  - Is preparing for CARIBE EWS reports on sea level data availability in the region.
  - With funding from ICSECA ($25,000) has coordinated equipment delivery and training to the Coastal Zone Management Unit to install in Barbados a sea level station that meets the CARIBE EWS standard. It will also coordinate a meeting of Caribbean Sea Level stakeholders in the region to discuss the enabling of a Caribbean Sea level data archive and analysis system in Belize. This meeting was supposed to be held in September, but had to cancel due to weather conditions.
  - With funding secured from the US State Department (VCP), the CTWP will carry out the project “Enhancing Multipurpose Sea Level Monitoring and Forecasting Capabilities in the Caribbean and Adjacent Regions”. The purpose of this project is to improve sea level data availability, quality, management and usage in the Caribbean to enhance services of the Hydro Met offices and tsunami warning centers. As part of this project training, awareness and network building activities would be organized. Also on demand on site support will be provided to the operators and sea level data customers.

- NOAA and USAID/OFDA plan to cooperate with CTIC in the coming year and ITIC will work with CTIC to support their work plan. Activities are subject to available funding by NOAA, CTIC, ITIC, IOC, USAID/OFDA, and other sources, and approval by the ICG-VII). Included activities are:
  - Co-organize or conduct tsunami capacity building in coordination with CTWP. Possible trainings are
    - Regional or in-country tsunami warning and emergency response SOP training for TWFPs / DMOs (ITP-International, 1 wk hosted by country)
    - Tsunami Awareness training for DMOs and responders (1-day). Explore its feasibility and interest as part of CARIBE-EWS Caribbean preparedness program (such as TsunamiSmart or TsunamiReady), and/or as a train-the-trainer program for DMOs to use.
    - The US domestic course will be taught by ITIC and NDPTC in Puerto Rico April 23-27, 2012, and CTIC and CARIBE-EWS Member States are invited to attend.
    - Accept at least 1 person to ITIC Training Programme - Hawaii tsunami training (2 week, Hawaii, in 20-31 August 2012)
  - Provide ITIC / IOC tsunami awareness materials, including in Spanish in collaboration with Chile SHOA, CTWP and USAID.
  - Input to CTIC work plan, assistance in carrying out activities, and feedback to CTIC on its services.

- The Puerto Rico Seismic Network (PRSN) has numerous activities planned to support the regional partners:
  - Will relocate Samana seismic station in Dominican Republic to a safer location.
- Will reconnect the Punta Cana seismic Station in Dominican Republic.
- Will relocate the PUCM seismic station in the Dominican Republic. This is a joint effort with ISU Dominican Republic and US Universities University of Texas at Austin/Baylor University.
- Will install, with ONAMET and ISU a new tide gauge and seismic station in Barahona, Dominican Republic.

- The USGS and the Puerto Rico Strong Motion Program installed 13 strong motion stations in the Dominican Republic plans are to connect these stations in real time.
- The CTWP will support with NESDIS, NOS the 3rd Caribbean Sea Level operators workshop in Mexico in June 4-8, 2012.

NATIONAL PROGRAMMES AND ACTIVITIES INFORMATION

11. EXECUTIVE SUMMARY

The U.S. government support for the ICG CARIBE-EWS is an inter-agency collaboration lead by NOAA/NWS, and involves the USGS and Department of State, including USAID/OFDA.

The U.S. continues to operate two major Tsunami Warning Centers in support of the Intergovernmental Coordination Group for Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS). These Centers, the Pacific Tsunami Warning Center (PTWC) in Ewa Beach, Hawaii, and the West Coast and Alaska Tsunami Warning Center (WCATWC) in Palmer, Alaska, have real-time or near real-time access to data from large arrays of seismic and sea level stations spanning the world. The PTWC provides information bulletins and watch bulletins to the greater Caribbean region in the interim. The WCATWC provides Tsunami Warnings, Advisories, Watches, and Information Statements, and interpretative information to Puerto Rico, the Virgin Islands, Canada, and all U.S. coastal states except Hawaii. The TWCs collaborate closely with the Puerto Rico Seismic Network for earthquakes and potential tsunamis in the region. To support the capacity building and technical strengthening of Member State national tsunami warning and emergency response agencies in order to ensure timely and understandable responses to PTWC alerts, the U.S. operates in cooperation with the UNESCO/IOC the International Tsunami Information Center (ITIC). Per Recommendation ICG/CARIBE-EWS-VI.1 Caribbean Tsunami Information Center, the ITIC was requested to continue CTIC/ITIC collaboration in provision of education and training to the Caribbean region. During the intersessional period, the ITIC has reported a number of activities in support of CARIBE-EWS countries. As of February 1, 2010 NWS established the Caribbean Tsunami Warning Program, co-located with the Puerto Rico Seismic Network at the University of Puerto Rico in Mayagüez. This is the first step of the U.S. phased deployment of a Caribbean Tsunami Warning Center. The CTWP has been providing support for observational stations, collaborating with new forecast tools, offering technical and scientific guidance to stakeholders in the region and providing education and preparedness support in the region. It is anticipated it will have a role in generating forecasts and warnings in the future phases and as additional personnel is hired and it moves into a larger facility on the UPR campus.

12. NARRATIVE

In the United States (U.S.), the Tsunami Warning System (TWS) is operated by the National Weather Service (NWS) managing the warning centers, data buoys from the National Data
Buoy Center, and communications and dissemination capabilities. Another key component of the TWS, is from the NOAA National Ocean Service (NOS), is primarily responsible for the operation and maintenance of U.S. coastal sea level gauges. Tsunami research is conducted by NOAA’s Pacific Marine Environmental Laboratories (PMEL) and by various universities under the direction of the National Science Foundation (NSF). The World Data Service for Geophysics (WDC), including tsunamis, is operated by NOAA’s National Environmental Satellite, Data & Information Service’s (NESDIS) National Geophysical Data Center (NGDC). NESDIS also supports the TWS by providing communications from remote data platforms through NOAA’s Geostationary Operational Environmental Satellite (GOES). The U.S. Geological Survey (USGS) is responsible for seismological research and their National Earthquake Information Center (NEIC) assists the TWS through the provision of real-time seismic data and by cooperation and collaboration on other aspects of seismic data collection and analysis. NWS Weather Forecast Offices (WFOs) disseminate tsunami information, coordinate with partners, and collaborate with Emergency Managers. The National Data Buoy Center (NDBC) is responsible for the deployment, operation, and data management of the U.S. tsunameter network. NDBC fielded an upgrade to the tsunameters that allows U.S Tsunami Warning Centers to interrupt an on-going trigger mode and re-trigger a system to extend more frequent reporting in anticipation of a tsunami passage. NDBC implemented a metadata spreadsheet to which users can subscribe (using Really Simple Syndication protocol (RSS)) to alert them to changes of the status of the tsunameters (http://www.ndbc.noaa.gov/dart_metadata/dartmeta_public.php). TsunamiReady™ is a program that helps communities at risk. Schools, playgrounds, hospitals, factories, and homes are often built in areas vulnerable to tsunamis. The TsunamiReady™ Program, developed by the National Weather Service, is designed to help cities, towns, counties, universities and other large sites in coastal areas reduce the potential for disastrous tsunami-related consequences.

TsunamiReady helps community leaders and emergency managers strengthen their local operations. TsunamiReady communities are better prepared to save lives through better planning, education, and awareness. Communities have fewer fatalities and property damage if they have plans in place before a tsunami arrives. No community is tsunami proof, but TsunamiReady can help minimize loss to your community. As of April 2012, there are 20 TsunamiReady communities in Puerto Rico.

The U.S. has adopted a phased approach to developing a Caribbean Tsunami Warning System. There are three phases, each with a discrete decision point that determines whether to proceed to the next phase.

1 - Enhance tsunami outreach and education capacity in the Caribbean.
2 - Strengthen Caribbean Regional Tsunami monitoring
3 - Establish a Regional Tsunami Warning Center at the University of Puerto Rico Mayaguez

In the first phase (FY 2009), the U.S. hired a new Manager, Caribbean Tsunami Warning Program, located at the University of Puerto Rico in Mayaguez (recruitment of Professor Christa von Hillebrandt-Andrade was made by the NWS Regional Director, Bill Proenza, on January 7, 2010 and Professor Hillebrandt officially entered on duty with NWS at the University of Puerto Rico Campus at Mayaguez on February 1, 2010).

In the second phase, the U.S. will identify requirements for improvements to seismic networks, sea level (coastal and deep-ocean) networks, communications infrastructure, and other elements of a tsunami detection system for the Caribbean. The requirements will help inform
decisions about how the US can enhance these networks. The ITIC continues to work with the IOC and CTIC Barbados per the ICG/CARIBE request to support Member State requests for awareness materials and warning decision support tools in coordination with the Caribbean Tsunami Warning Program Manager.

In the third phase, the U.S. with Agency and Executive approval plus Congressional appropriations will establish a tsunami warning center co-located with the Puerto Rico Seismic Network at the University of Puerto Rico at Mayaguez.

It is important to note that these phases are planning phases, not implementation phases. The results and timing of each phase will determine next steps, including decisions about whether or not to continue the planning process. The U.S. will inform and consult with the ICG/CARIBE-EWS Member States as we go through this process.

Tsunami communication tests are conducted by the PTWC to member states and the WC/ATWC with Puerto Rico and the U.S. Virgin Islands to check for correct contact information – includes, phone numbers, fax lines and sometimes email addresses.

The International Tsunami Information Center, in existence since 1965, is a partnership of the UNESCO/IOC and NOAA, with a mission to help countries establish and strengthen their national tsunami warning and mitigation systems. It does this through technical assistance and training, development and distribution of awareness and educational materials, and other information services. For event data archiving and development of tsunami awareness and support products, it works closely with the NOAA National Geophysical Data Center (NGDC), which serves as the World Data Service for Geophysics, including Tsunamis, PTWC, USGS, and other partners. Since 2007, the ITIC and NGDC have collaborated to develop and distribute several awareness products and warning decision support tools. In 2006, the ICG/CARIBE-EWS requested the services of ITIC on an as-needed basis, and in 2011, requested the ITIC to continue CTIC/ITIC collaboration in provision of education and training to the Caribbean region ITIC has assisted by conducting tsunami training in 2007 in collaboration with the USGS, provided guidance for the implementation of the Caribbean Tsunami Information Center (CTIC) in Barbados, provided awareness materials and decision support tools to Member States, and served as a technical consultant to the CDEMA project of the development of Local Standard Operating Procedures. The ITIC will continue to support the CTIC work plan in cooperation with CTWP.

In the U.S., the ITIC has developed 1-day Tsunami Awareness Course (AWR-217) for the U.S. Department of Homeland Security National Disaster Preparedness Training Center that has been available to all U.S. coastal communities since January 2011. The course will be delivered four times in Puerto Rico April 23-27, 2012, and CARIBE-EWS Member States and the CTIC are invited to participate, and consider whether a similar international course would be beneficial for the region.

Date: ................................. Name: .................................