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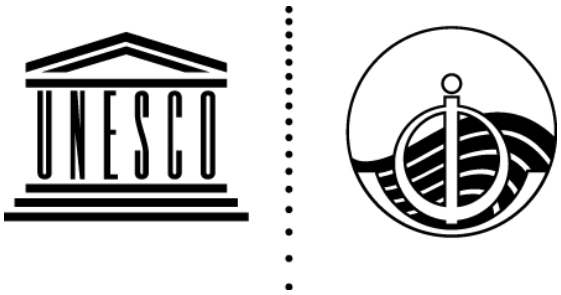

EXERCISE CARIBE WAVE 17

A Caribbean and Adjacent Regions Tsunami Warning Exercise

21 March 2017 (Costa Rica, Cuba and Northeastern Antilles Scenarios)

Final Report Volume 2

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Report prepared by: Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS)

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Summary

Around seven hundred thousand people from Bermuda through Brazil and across the entire Caribbean basin participated in the CARIBE WAVE 17 tsunami exercise held on March 21, 2017. This represents an increase of 102% from 2016 (332,812 participants). This level of participation makes CARIBE WAVE exercise again the largest international tsunami drill in the world. The participants in the sixth annual regional exercise hailed from 32 nations and 15 territories[1] of the UNESCO Intergovernmental Coordination Group for Tsunamis and other Coastal Hazards for the Caribbean and Adjacent Regions (CARIBE EWS).

Registered participants included designated CARIBE EWS Tsunami Warning Focal Points (TWFPs) and National Tsunami Warning Centers (NTWCs), as well as emergency and preparedness organizations, K-12 Schools, government agencies, colleges and universities, healthcare and hotels, critical facilities, among others.

Each country chose one of the three CARIBE WAVE 2017 scenarios: Costa Rica, Cuba or Northern Lesser Antilles. Over 65 simulated international and domestic messages were disseminated by the Pacific Tsunami Warning Center (PTWC).

Sirens, emails, emergency alert systems, text messages, media outlets, NOAA weather radio, and social media were used for local dissemination. In addition to the communication tests, exercises were conducted at various levels of magnitude and sophistication including seminars, tabletop exercises, video/web conferencing, drills and full scale exercises as for the French Antilles with mobilization of aid forces from Europe.

Through the exercise it has been possible to validate the **issuance** of tsunami products from the PTWC, the **receipt and dissemination** of tsunami products within the countries, familiarization with the PTWC messages and **the readiness of the Caribbean and Adjacent Regions** to respond to a tsunami.

Planning for CARIBE WAVE 17 has taken over a year and was coordinated by a task team led by Lt. Col. Patrick Tyburn of France and facilitated by the US NWS Caribbean Tsunami Warning Program. TsunamiZone.org was used for the registration of the participants. Information and supporting documents were and will remain posted on http://caribewave.info. The exercise was conducted under the framework of the CARIBE EWS which was established by UNESCO IOC in 2006 after the devastating Indian Ocean Tsunami and the recognition of the high tsunami threat in the Caribbean.

1. BACKGROUND

The UNESCO IOC Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions at its eighth session (ICG/CARIBE EWS-VIII, Port of Spain, Trinidad and Tobago, 29 April - 1 May 2013), decided to conduct exercises named CARIBE WAVE on an annual basis leaving each Member State to define its level of participation. At its Eleventh Session in Cartagena de Indias, Colombia, 5-7 April 2016, the ICG/CARIBE-EWS, recommended that Exercise CARIBE WAVE 17 take place on 21 March 2017, with three hypothetical tsunami scenarios generated by earthquakes: off the Caribbean coast of Costa Rica (Plafker and Ward, 1992), off the southeastern coast of Cuba (Calais and Lepinay, 1991), and East of the Northeastern Lesser Antilles (Hayes et al.,

[1] Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Brazil, Colombia, Costa Rica, Cuba, Curacao, Dominica, Dominican Republic, France (Martinique, Guadeloupe, St. Barthelemy, St. Martin), Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Netherlands (Bonaire, Saba and Sint Eustatius), Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Sint Maarten, Suriname, Trinidad and Tobago, United Kingdom (Anguilla, British Virgin Islands, Bermuda, Cayman Islands, Montserrat and Turks and Caicos), United States (Puerto Rico and the US Virgin Islands) and Venezuela (Bolivarian Republic of).

2013).

Historical tsunami records from sources such as the National Oceanic and Atmospheric Administration's (NOAA) Centers for Environmental Information (NCEI) show that 4,400 people have been killed as a result of almost 75 tsunamis have been observed in the Caribbean. Potential sources for tsunamis in the region include faults, steep slopes offshore, subaerial and submarine volcanoes. The region east of the Azores Islands and portions of the continental slope off the US and Canadian coast are particularly vulnerable to subsea landslides, which could also reach the Caribbean and Adjacent Regions.

Recognizing the need for an early warning system especially after the lessons learned from the 2004 Indian Ocean tsunami, the Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE EWS) was established in 2005 as a subsidiary body of the IOC-UNESCO with the purpose of providing assistance to all Member States of the region to establish their own early warning system. The main objective of the CARIBE EWS is to identify and mitigate the hazards posed by local, regional and distant tsunamis. The ultimate goal is to create a fully integrated end-to-end warning system comprising four key components: monitoring and detection systems, hazard assessment, tsunami related services (dissemination), and community preparedness, readiness and resilience.

The 2017 exercise provided simulated threat tsunami messages from the PTWC triggered by three hypothetical earthquakes: a 7.9 Mw with an epicentre at 9.37°N, 82.54°W, off the Caribbean coast of Costa Rica (Fig. 1), in the southern Caribbean Sea, a 8.2 Mw with an epicentre at 19.625°N, 76.35°W, off the southeastern coast of Cuba (Fig. 2), in the northwestern portion of the Caribbean Sea, and a 8.5 Mw with an epicentre at 16.96°N, 60.69°W, East of the Northeastern Lesser Antille (Fig. 3). The three scenarios were based on referenced events, which occurred on April 22, 1991, February 11, 1775, and February 8, 1843 (www.ngdc.noaa.gov/) respectively.

At the national level, each member state was responsible for defining its level of participation, which could include issuing warnings or other alerts to its own citizens. These alerts could be based either on the TWFP's own analysis of the situation or the messages and/or graphical products received from the PTWC.

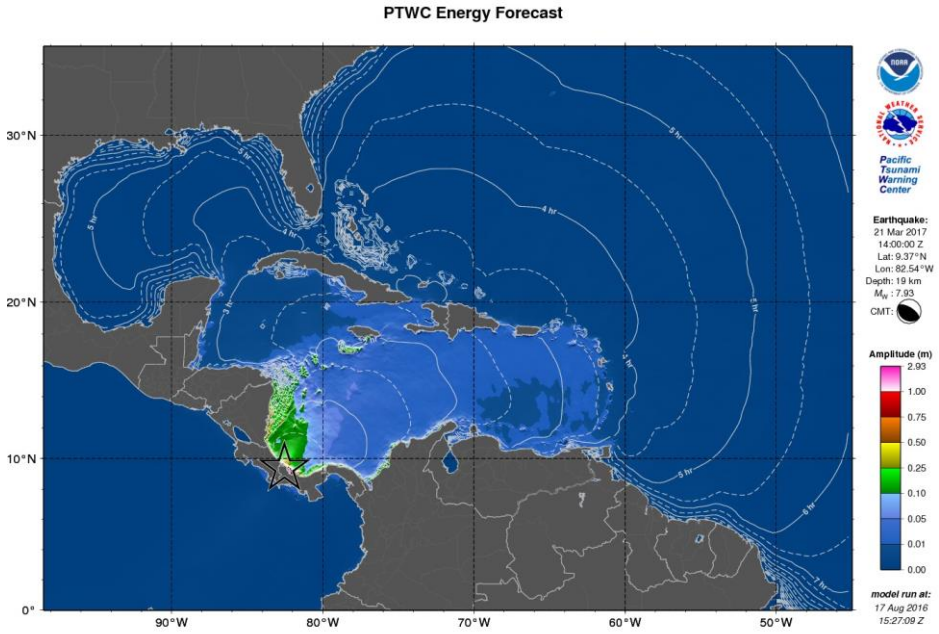

Figure 1. RIFT maximum amplitude map for the Southern Caribbean Sea based on the scenario for Costa Rica.

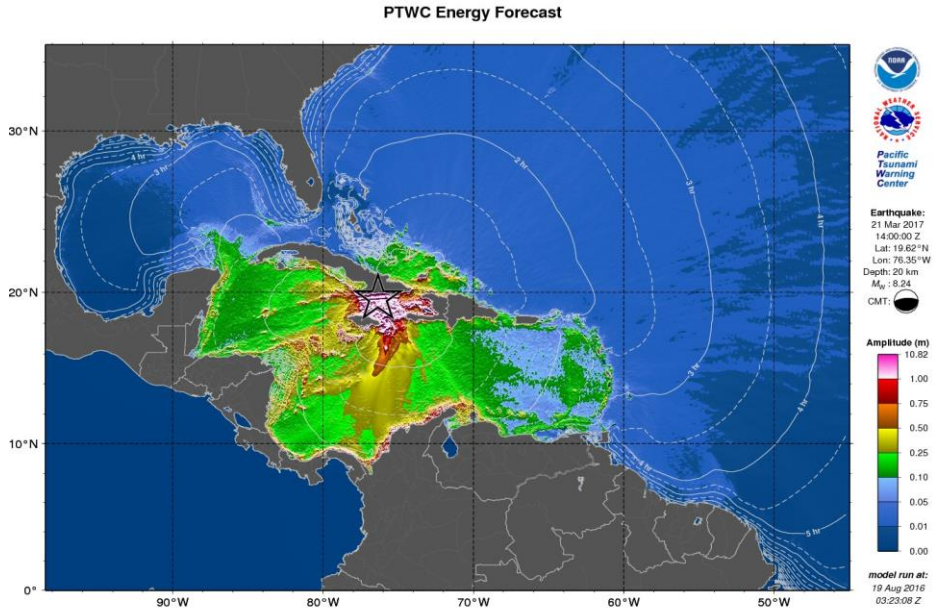

Figure 2. RIFT maximum amplitude map for the Northwestern portion of the Caribbean Sea scenario for Cuba.

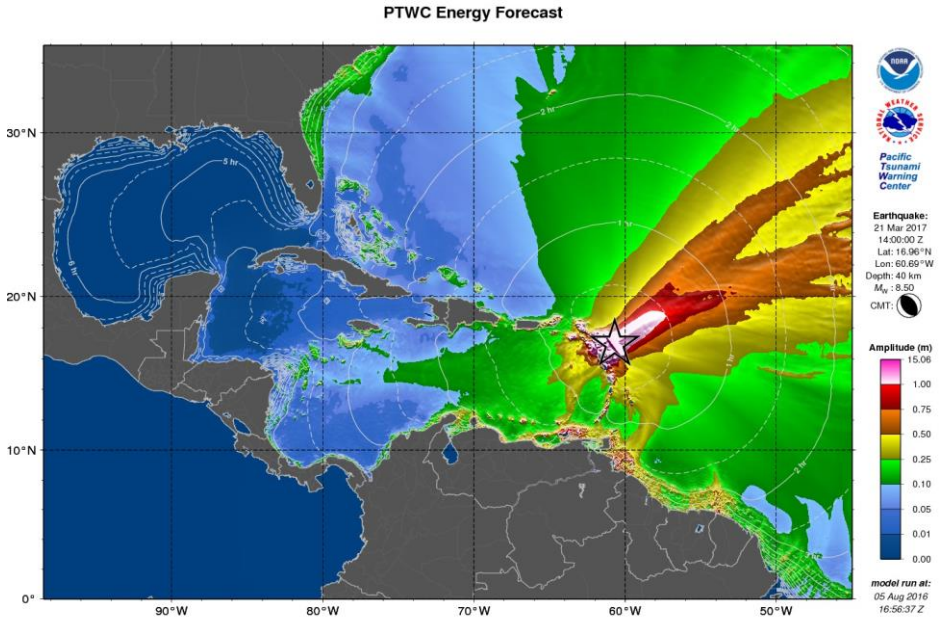

Figure 3. RIFT maximum amplitude map for the Southeastern portion of the Caribbean Sea scenario for Northeastern Lesser Antilles**.**

2. EXERCISE CONCEPT

2.1 PURPOSE

The purpose of the exercise was to improve Tsunami Warning System effectiveness along the Caribbean coasts. The exercise provided an opportunity for emergency management organizations (EMOs) throughout the region to exercise their operational lines of communications, review their tsunami response procedures, and promote tsunami preparedness. Regular exercising of response plans is critical to maintain readiness for an emergency. This is particularly true for the Caribbean and Adjacent regions, where tsunamis are infrequent but can be of very high impact. Every emergency management organization was encouraged to participate.

2.2 OBJECTIVES

Each organization was asked to develop their objectives for the exercise. However, there were three principal overarching objectives. First, exercise and evaluate operations of the CARIBE EWS Tsunami Warning Systems, specifically validate the issuance from the PTWC and receipt of tsunami products by CARIBE EWS Tsunami Warning Focal Points (TWFPs) and/or National Tsunami Warning Centers (NTWCs). Second, evaluate enhanced PTWC products and to provide further feedback on the national procedures for implementation of these products. Third, validate and improve the operational readiness of the TWFPs, and/or the National Disaster Management Office (NDMO) to respond to a local/regional source tsunami, before, during and after the exercise, to ensure that appropriate tools and response plan(s) have been developed, including public education materials. Additionally, validate that the dissemination of warnings and information/advice by TWFPs, and NTWCs, to relevant in-country agencies and the public is accurate and timely. Also, validate the organizational decision-making process (tsunami response plans) about public warnings and evacuations. Likewise, evaluate the status of implementation of the Tsunami Ready program of the CARIBE EWS.

2.3 TYPE OF EXERCISES

The exercise was carried out such that communications and decision making at various organizational levels were exercised and conducted without disrupting or alarming the general public. A majority of National and local Offices of Emergency Management (OEM) extended the exercise down to the level of testing local notification systems such as the Emergency Alert System (EAS), sirens and loudspeakers.

According to the registrations and Member States reports, 679,985 people throughout the Caribbean and Adjacent Regions participated in the exercise. This represents an increase of 102% participation from 2016 (332,814 participants), 2015 and 2014 (~191,000 participants) and fifteen-fold increase (50,000 participants) since 2013 (IOC Caribe Wave 16, Volume 2: Final Report, June 2016). This level of participation makes again the CARIBE WAVE exercise the largest international tsunami drill in the world. The participants in the sixth annual regional tsunami exercise hailed from 32 nations and 15 territories. It represented a participation rate of 100% of all the Member States of the UNESCO Intergovernmental Coordination Group for Tsunamis and other Coastal Hazards for the Caribbean and Adjacent Regions (CARIBE EWS) which provided the framework. Participants included all officially designated CARIBE EWS Tsunami Warning Focal Points (TWFPs), International, State, Territorial and Local Emergency Management Organizations, Schools and Universities, Governmental Agencies, Private Organizations, Health Facilities, Members of the Media, as well as Communities, Individuals and Families.

Exercises were conducted at various scales of magnitude and sophistication. Exercises simulated the development, training, testing, and evaluation of Disaster Plans and Standard Operating Procedures. The following types of exercises were reported to have been conducted: seminars, tabletop exercises, drills and full scale exercises (Fig. 4).

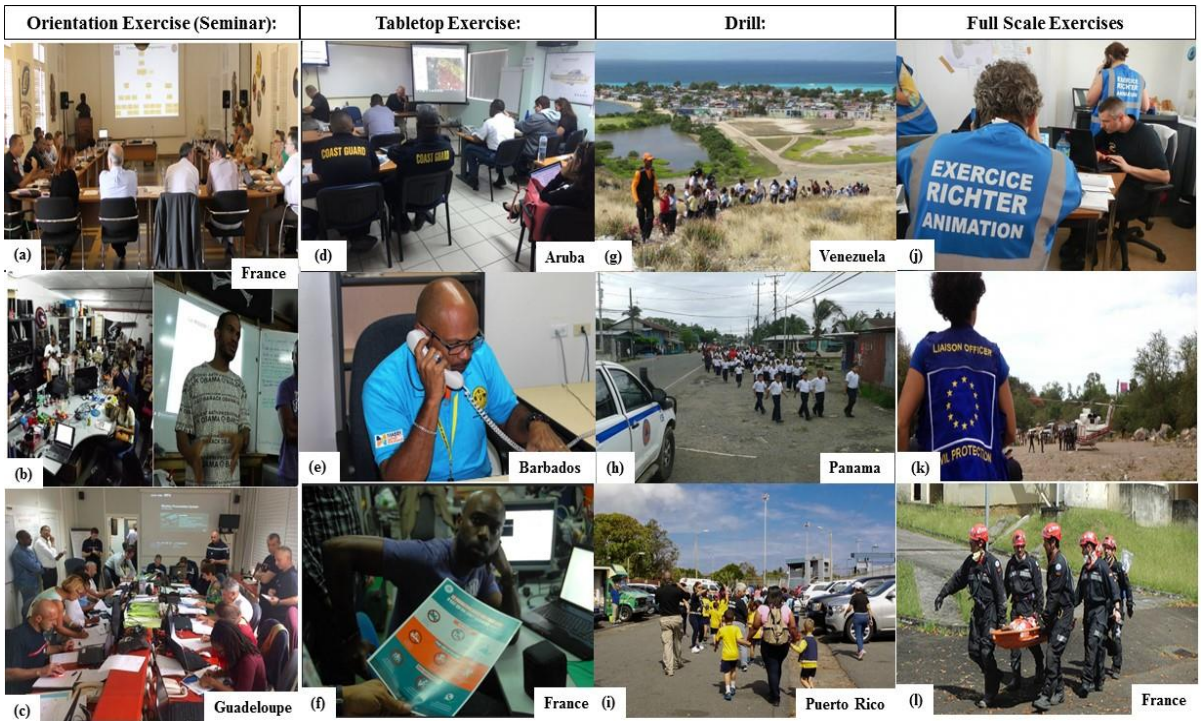

Figure 4. Types of exercises examples as part of the CARIBE WAVE 17: orientations exercise in France (a and b) and Guadeloupe (c); tabletop exercises in the US, Pacific Tsunami Warning Center, Aruba (d), Barbados (e), and France (f); drills in Venezuela (g), Panamá (h) and Puerto Rico (i); full scale exercises in French territories.

3. EXERCISE OUTLINE

3.1 GENERAL

Tsunami messages for this exercise were issued by the PTWC based on three hypothetical earthquakes with the following hypocenter parameters:

Costa Rica Earthquake Scenario:
- Origin Time 14:00:00 UTC March 21, 2017
- Latitude 9.37º
- Longitude -82.54º
- Magnitude 7.9 – Mw
- Depth 19 km

Cuba Earthquake Scenario:
- Origin Time 14:00:00 UTC March 21, 2017
- Latitude 19.625º
- Longitude -76.35º
- Magnitude 8.2 – Mw
- Depth 20 km

Northeastern Antilles Earthquake Scenario:
- Origin Time 14:00:00 UTC March 21, 2017
- Latitude 16.96º
- Longitude -60.69º
- Magnitude 8.5 – Mw
- Depth 10 km

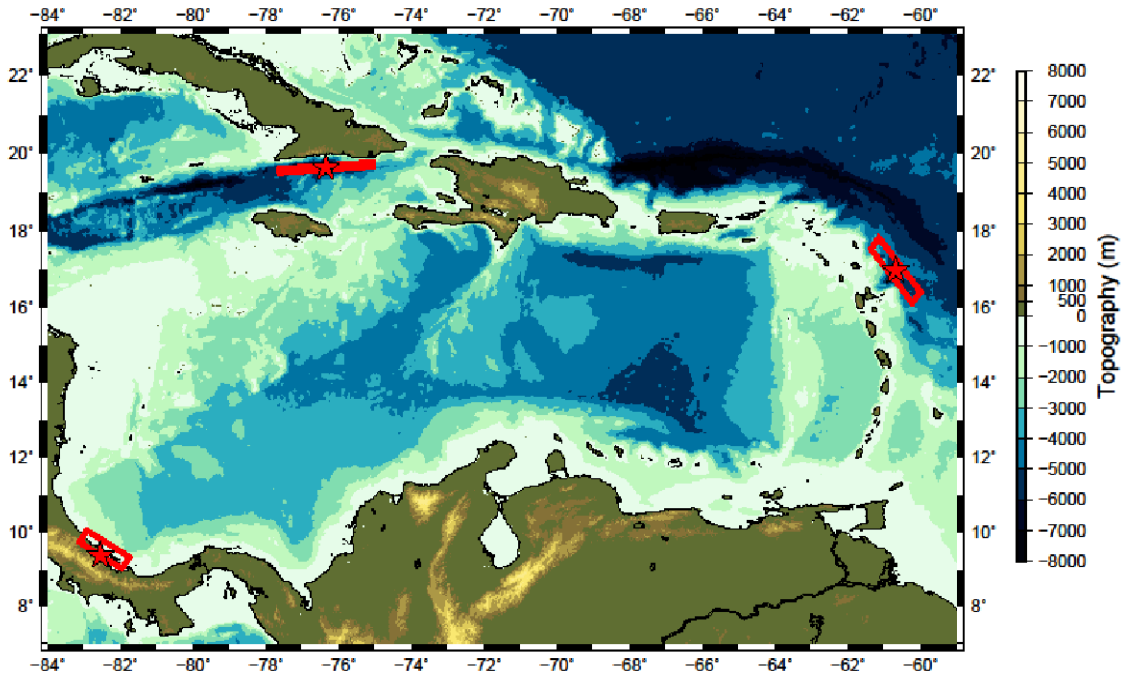

Figure 5. CARIBE WAVE 17 scenario map indicating epicenters and fault segments, underlain using etopo1 model (Amante and Eakins, 2009). The Generic Mapping Tool (GMT) generated the figure (Wessel et al., 2013).

Messages Issued by the PTWC

The PTWC issued over 65 simulated messages for CARIBE WAVE 17. The first tsunami threat message for each of the scenarios was based on the earthquake magnitude and location and the tsunami travel times. While as of the second messages were based on tsunami wave forecasts, rather than upon seismic information. Tsunami threat forecasts indicated the levels of threat that have been forecast and to which countries or places they apply. The levels are tsunami heights of 0.3-1 meter, 1-3 meters, and greater than 3 meters above the normal tide level are determined. The threats were updated usually within an hour.

For the 2017 exercise, the Member States were required to select one scenario by March 10, 2017, and those who did not select any scenario, got messages for the scenario that the Caribe Wave organizers selected for them. For the exercise, only the TWPFs/ NTWCs received the simulated products for the chosen scenario. All simulated products (text and graphical) were disseminated through email to the corresponding TWFPs and NTWCs. Further dissemination was the responsibility of the corresponding national and local authorities.

The PTWC also issued live over all standard broadcast channels (WMO/AWIPS IDs WECA41 PHEB/TSUCAX) the initial dummy message to start the exercise at 1400 UTC on March 21, 2017.

3.2 MASTER SCHEDULE (EXERCISE SCRIPT)

The initial dummy message for the three scenarios was issued by the CARIBE EWS Tsunami Service Provider (PTWC) on March 21, 2017 at 1400 UTC. This was to test communications with TWFPs and NTWCs, and to start the exercise. The transmission methods used to send the dummy message were GTS - WIS (WMO Information System), EMWIN, AISR, NWWS, Email, Fax and AWIPS (Advanced Weather Interactive Processing System), using header IDs WECA41 PHEB/TSUCA. All simulated products (text and graphical) were disseminated only through email to TWFPs and NTWCs. Seven threat messages were issued for Costa Rica scenario and nine threat messages were issued each for the Cuba and Northeastern Lesser

Antilles scenarios. The graphic enhanced products were included in the second threat message. The TWFPs reportedly used a variety of methods to receive the Dummy message, with Fax and Email being the most common (Fig. 6).

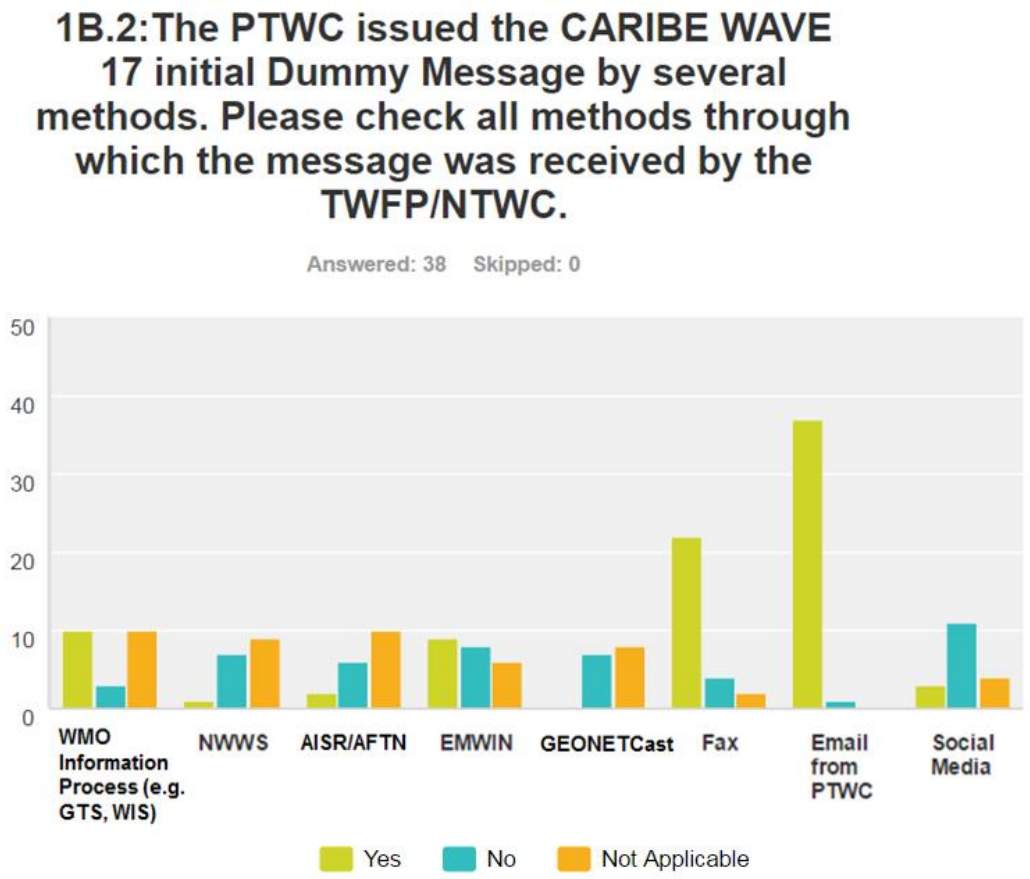

Figure 6. Methods that the CARIBE EWS TWFPs/NTWCs used to receive the Dummy message by the PTWC.

3.3 ACTIONS IN THE CASE OF A REAL EVENT, AND FALSE ALARMS

No significant real events and false alarms were reported by the Member States and Territories during the exercise. No actions were thus required.

3.4 REGISTRATIONS PROCEDURE

As for the 2016 exercise, the CARIBE EWS teamed up with TsunamiZone.org for online registration. The link used for the registration was http://www.tsunamizone.org/register/. Under the “Register Here” Tab participants were able to sign up and choose among the following categories: individuals, businesses, schools, faith-based organizations, community groups, government agencies (including TNCs. TWFPs and NTWCs), and individuals (Fig. 7). EMOs were encouraged to promote this registration system.

Most people registered directly on the TsunamiZone.org which is an open registration system all year around. Some Member States provided in the post-exercise survey, estimates on how many people participated (own statistics). The final number of participants was 747,326 (Tables 1 and 2).

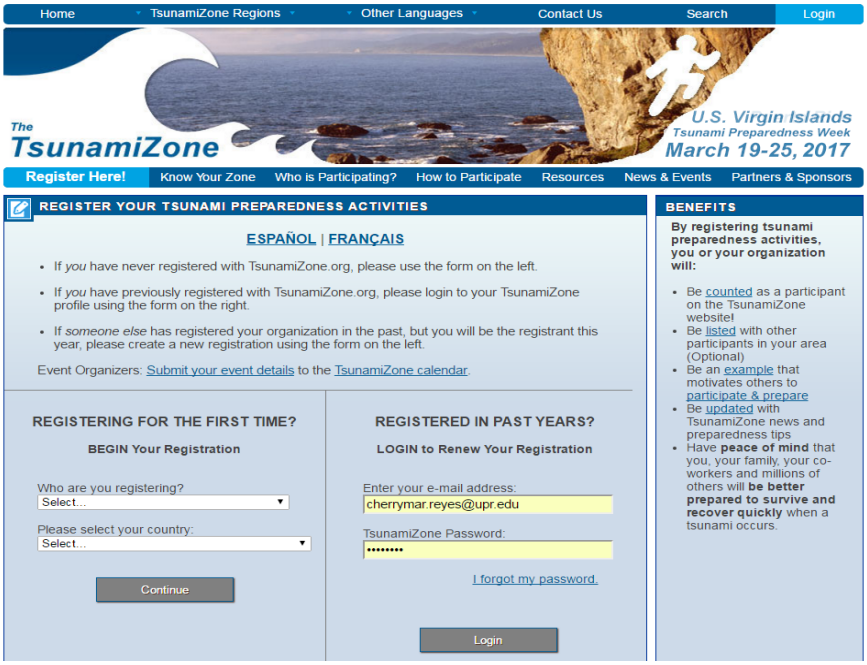

Figure 7. Registration by categories and Country for the CARIBE WAVE 17 Regional Tsunami Exercise.

Table 1. List of registrants and participants by Categories on TsunamiZone.org (as of 7/5/2017)

Category	Number of Participants
Individuals/Families	1,199
Childcare and Pre-Schools	4,523
K-12 Schools and Districts	133,322
Colleges and Universities	42,855
Government*	231,674
Businesses	1,415
Hotels and Other Lodgings	443
Healthcare	5,908
Senior Facilities/Communities	170
Disability/AFN Organizations	306
Non-Profit Organizations	2,023
Neighborhood Groups	53
Preparedness Organizations	25,617
Faith-based Organizations	14,060
Museums, Libraries, Parks, etc.	70
Volunteer/Service Clubs	801
Agriculture/Livestock	50
Volunteer Radio Groups	343
Science/Engineering Organizations	387
Media Organizations	35
Other	197,979
Total	663,233

*This includes TWFPs and TNCs

Table 2. List of participants by Country/Territory (as of 7/5/2017)

Country	Number of Participants who directly registered on TsunamiZone	Number of Participants according to Member States	Consolidated Number of Participants
Anguilla	1,250	600	1,250
Antigua and Barbuda	3,392	5,000	5,000
Aruba	26	9,407	9,407
Bahamas	5	-	5
Barbados	305	250	305
Belize	5	6	6
Bermuda	160	6	160
Bonaire	10	20	20
Brazil	10	-	10
British Virgin Islands	7,024	7,113	7,113
Cayman Islands	20,102	30,000	30,000
Colombia	34	40	40
Costa Rica	15	50	50
Cuba	17	1,000	1,000
Curaçao	143	30	143
Dominica	170	72	170
Dominican Republic	993	977	993
France (Guadeloupe, Maritinique, Saint Barthélemy, Saint Martin)	16	-	16
Grenada	21,705	20,000	21,705
Guadeloupe	42,058	62,183	62,183
Guatemala	10	10	10
Guyana	21	-	21
Haiti	2,891	2,891	2,891

Country	Number of Participants who directly registered on TsunamiZone	Number of Participants according to Member States	Consolidated Number of Participants
Honduras	510	2,000	2,000
Jamaica	7	5	7
Martinique	73,784	63,839	63,839
Mexico	401	1,000	1,000
Montserrat	20	-	20
Netherlands	6	20	20
Nicaragua	30	30	30
Panama	7,102	7,000	7,102
Puerto Rico	153,401	153,398	153,401
Saba	0	-	0
Saint Barthélemy	0	1,500	1,500
Saint Kitts and Nevis	2,611	2,500	2,611
Saint Lucia	2,606	2,600	2,606
Saint Martin	10	5,000	5,000
Saint Vincent and the Grenadines	6	7	7
St Eustatius	20	-	20
Sint Maarten	500	1,900	1,900
Suriname	20	-	20
Trinidad and Tobago	11,234	11,100	11,234
Turks and Caicos	35	35	35
U.S. Virgin Islands	2,135	2,135	2,135
Venezuela	116,086	283,000	283,000
TOTAL	470,886	676,124	679,985

3.5 STATUS OF SEA LEVEL STATIONS DURING EXERCISE

A full analysis of sea level status was completed by the CTWP as part of the CARIBE WAVE 17 Regional Tsunami Exercise. This analysis permitted the evaluation of sea level data that would have been available in the case of a real event at the time of the exercise. The PTWC provided forecasted maximum wave heights for a number of stations in the simulated bulletins, 45 for Costa Rica, 68 for Cuba, and 81 for Northeastern Lesser Antilles. Of these, 47 (55%) were reporting to the IOC Sea Level facility during the exercise time frame. In the case of Tide

Tool (Fig. 8, 9 and 10), 45 out of 83 stations had data available. Of the 17 stations that should be available on the NOAA Tides and Currents for the Caribe/Central America, 9 stations (62%) had data. In the case of the DART, 6 of 7 in the Caribbean/Gulf and Atlantic had data streaming through the National Buoy Center. A complete summary for the stations' sea level data availability can be found in the Supplement.

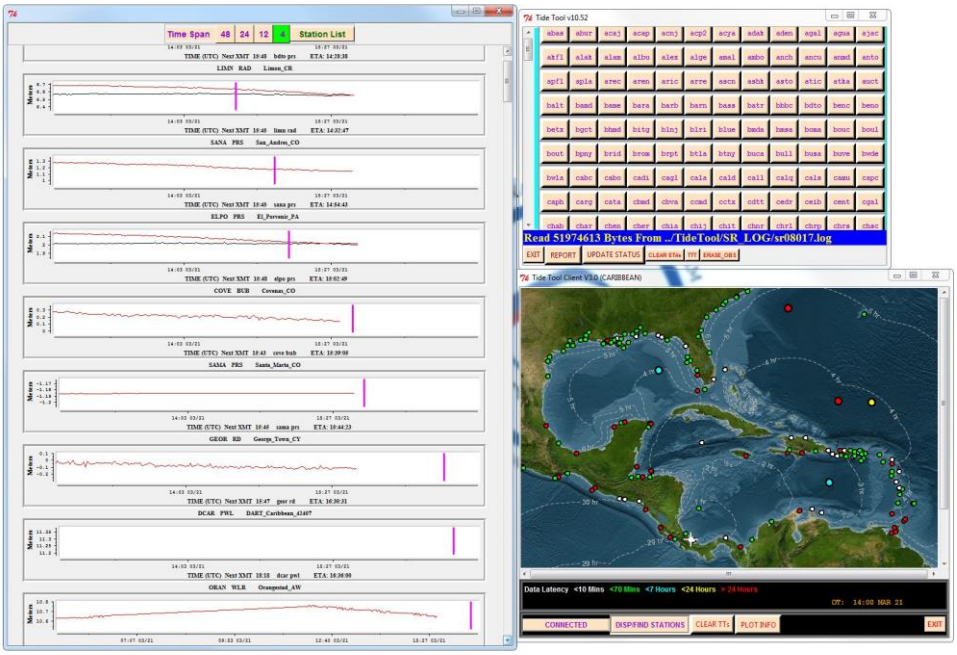

Figure 8. Screen shot showing Tide Tool data for the CARIBE WAVE 17 Costa Rica Scenario.

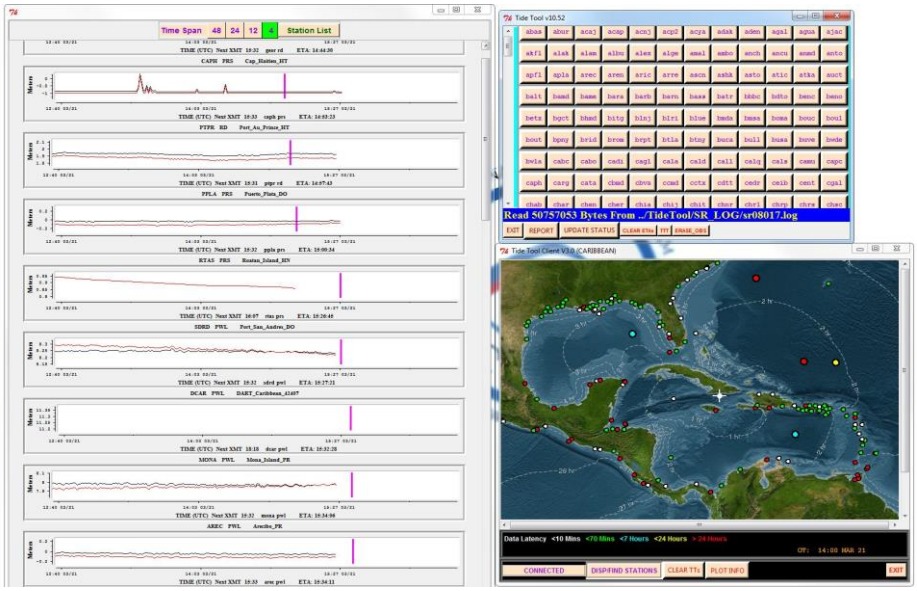

Figure 9. Screen shot showing Tide Tool data for the CARIBE WAVE 17 Cuba Scenario.

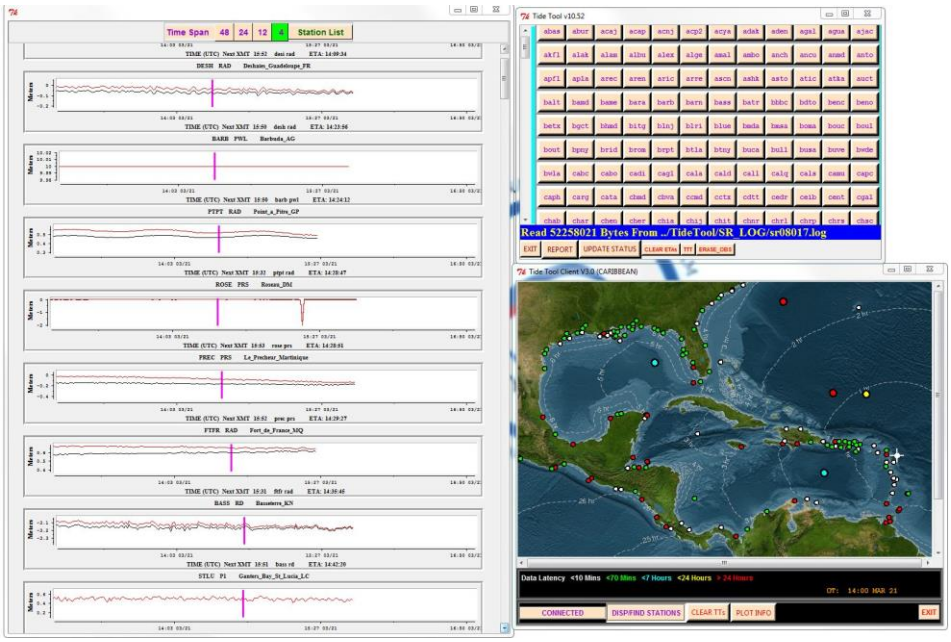

Figure 10. Screen shot showing Tide Tool data for the CARIBE WAVE 17 Northeastern Lesser Antilles Scenario.

3.6 TSUNAMI FORECASTING USING TWEB

For the exercise, simulated tsunami forecasts were also generated for the Costa Rica, Cuba and Northeastern Lesser Antilles scenarios using Tweb, a web-based and cloud-capable tsunami forecasting tool under development by the NOAA Center for Tsunami Research (NCTR) (nctr.pmel.noaa.gov/twebinfo/). Tweb implements the NOAA Method of tsunami forecasting by detecting the seismic event, defining a basin wide forecast, running high-resolution models for risk areas, and integrating DART data. This forecasting tool is in testing phase and is currently being evaluated by NOAA researchers, domestic and international collaborators, NTWCs, ComMIT users, and emergency managers in non-operational mode. For detailed information, the Supplement shows a complete description of the modeling and tsunami forecasts produced for the exercise.

3.7 RESOURCES

Although EMOs had notice of the exercise and some elected to set up a special dedicated shift to allow normal core business to continue uninterrupted, it was requested that realistic resource levels be deployed in order to reflect some of the issues that are likely to be faced in a real event. This year the exercise chair was Patrick Tyburn; while Silvia Chacón and Natalia Zamora (Costa Rica), Bladimir Moreno (Cuba), and Valerie Clouard (Northeastern Lesser Antilles) were the scientific experts that helped in the determination of the scenarios for the exercise. The CTWP coordinated the exercise for CARIBE EWS.

3.8 MEDIA ARRANGEMENTS

One advantage in conducting exercises is that it provides a venue to promote awareness of the exercise topic. The exercise offered an opportunity to partner with the media and disseminate more broadly information on the warning system. **Fifty eight percent of the CARIBE EWS Member States and Territories indicated that the news media participated and covered the exercise.** Exercise messages were disseminated and community participation was also encouraged through social media outlets such as Facebook and Twitter. The hashtag #CaribeWave was suggested to be used by participants. Hashtracking services indicated #CaribeWave had 3,157 tweets the month of March with a peak during the exercise (Fig. 11). During the exercise, users with US carrier providers received Tweets as text

messages (Fig. 12). News of press releases (Fig. 13) and media outputs can be found in the IOC Caribe Wave 17, Volume 3: Media Report, May 2017.

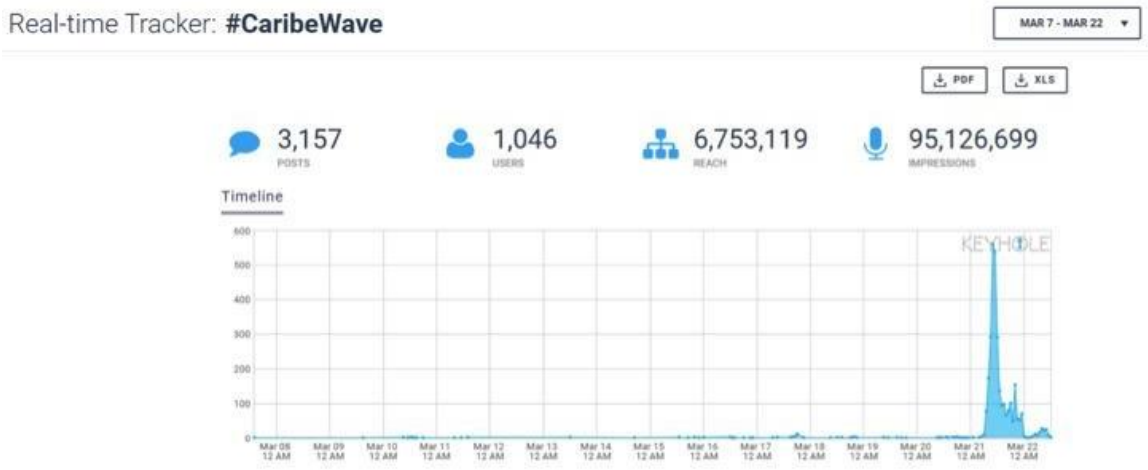

Figure 11. Graph showing the #CaribeWave trending between the 7th and 22th of March 2017.

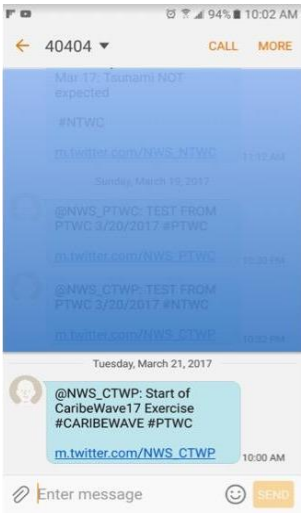

Figure 12. Start of exercise example during Caribe Wave 17.

Figure 13. Press conference at Puerto Rico State Emergency Management Agency for Caribe Wave 17.

4. POST-EXERCISE EVALUATION

All participating agencies were requested to provide feedback on the exercise. This feedback assists the ICG/CARIBE-EWS in the evaluation of CARIBE WAVE 17 and the development of subsequent exercises, and helps response agencies document lessons learned. The survey was conducted by the IOC UNESCO using Survey Monkey service. It contained 64 questions. **The survey was completed by 38 TNCs/TWFPs CARIBE EWS Member States and Territories which represent 32 Member States and 15 territories, including Brazil.** The questions as well as the answers and comments are contained in the Supplement. This questionnaire has a wealth of information that is important for the evaluation and planning of tsunami exercises but reflects an improved level of tsunami preparedness in the region.

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Appendix A. List of Acronyms

Acronym	Definition
ATFM	Alaska Tsunami Forecast Model
AWIPS	Advanced Weather Interactive Processing System
CDEMA	Caribbean Emergency Management Agency
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres Naturales en América Central
CTWP	US National Weather Service Caribbean Tsunami Warning Program
EAS	Emergency Alert System
EMO	Emergency Management Organization
EMWIN	Emergency Management Weather Information Network
FUNVISIS	Fundación Venezolana de Investigaciones Sismológicas
GTS	Global Telecommunication System
ICG CARIBE EWS	Intergovernmental Coordination Group for the Tsunamis and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions
INETER	Instituto Nicaragüense de Estudios Territoriales
IOC	Intergovernmental Oceanographic Commission
NGDC	National Geophysical Data Center (renamed to National Centers for Environmental Information - NCEI)
NOAA	National Oceanic and Atmospheric Administration
NTWC	US National Tsunami Warning Center (renamed from West Coast and Alaska Tsunami Warning Center on Oct. 1, 2013)
NTHMP	National Tsunami Hazard Mitigation Program
NWS	National Weather Service
PRSN	Puerto Rico Seismic Network
PTWC	Pacific Tsunami Warning Center
RIFT	Rapid Inundation and Forecasting of Tsunamis
TIB	Tsunami Information Bulletin
TWC	Tsunami Warning Center
TWFP	Tsunami Warning Forecast/Focal Point
UNESCO	United National Educational, Scientific, and Cultural Organization
WC/ATWC	West Coast and Alaska Tsunami Warning Center (renamed to NTWC on Oct. 1, 2013)
WFO	Weather Forecast Office
WMO	World Meteorological Organization

IOC Technical Series

No.	Title	Languages
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