Intergovernmental Oceanographic Commission
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157

EXERCISE CARIBE WAVE 21

A Caribbean and Adjacent Regions Tsunami Warning Exercise

11 March 2021 (Jamaica and Northern Lesser Antilles Scenarios)

Volume 2 Summary Report

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UNESCO 2021

IOC Technical Series, 157 (volume 2)
Paris, September 2021
English only

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NOTE: The United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Intergovernmental Oceanographic Commission (IOC) pattern the contents of this handbook after the CARIBE WAVE 2011, 2013, 2014, 2015, 2016, 2017, 2018 and 2019 Exercises. Each of these exercises has a handbook published as IOC Technical Series. These CARIBE WAVE exercises followed the Pacific Wave exercises which commenced in 2008 with manual published by the Intergovernmental Oceanographic Commission (Exercise Pacific Wave 08: A Pacific-wide Tsunami Warning and Communication Exercise, 28–30 October 2008, IOC Technical Series, 82, Paris, UNESCO 2008). The UNESCO How to Plan, Conduct and Evaluate Tsunami Wave Exercises, IOC Manuals and Guides, 58 rev., Paris, UNESCO 2013 (English and Spanish) is another important reference.

For bibliographic purposes, this document should be cited as follows:

UNESCO/IOC. 2021. *Exercise CARIBE Wave 2021. A Caribbean and Adjacent Region Tsunami Warning Exercise, 11 March 2021 (Jamaica and Northern Lesser Antilles Scenarios). Volume 2: Summary Report.* Paris, UNESCO, IOC Technical Series No 157, Vol. 2. (English only)

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Published in 2021
by United Nations Educational, Scientific and Cultural Organization
7, Place de Fontenoy, 75352 Paris 07 SP

(IOC/2020/TS/157 Vol.2)

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Summary

The CARIBE WAVE exercise is conducted within the framework of the UNESCO Intergovernmental Coordination Group for Tsunamis and other Coastal Hazards for the Caribbean and Adjacent Regions (CARIBE-EWS) with the purpose of improving and validating tsunami readiness. The exercise took place on March 11, 2021 in commemoration of the 10th anniversary of the Tohoku earthquake and tsunami in Japan. Despite the ongoing COVID-19 pandemic, CARIBE WAVE 21 was held successfully with a participation of forty-seven of its forty-eight Member States and Territories*. It was left up to the Member States and Territories to determine if any additional activity would be carried out and whether to use the simulated messages for one of the two scenarios: Jamaica and Northern Lesser Antilles.

According to preliminary information, more than 300,000 people across the entire Caribbean basin participated in the CARIBE WAVE 21 exercise. The majority of the participants were from National, State, and Local government, followed by preparedness organizations, and K-12 schools. The high participation rate reflects the importance the countries are giving to tsunami preparedness despite the ongoing a pandemic.

The Pacific Tsunami Warning Center (PTWC) issued a “Dummy” message at 14h00 to all officially designated Tsunami Warning Focal Points (TWFPs) and National Tsunami Warning Centers (NTWCs). The methods of communication used to disseminate the message were: The World Meteorological Organization Warning Information System (Global Telecommunication System), the Aeronautical Information Replacement System (AISR), NOAA Weather Wire, GEONETCAST Americas, AWIPS, Fax, Email and Social Media. According to feedback, as well as social media and web posts, the dummy message was successfully sent and received, validating the communication platforms. In addition to communication tests, exercises were conducted at various levels and sophistication including seminars, tabletops, and drills. These activities were executed taking into consideration the CARIBE EWS COVID-19 guidelines (English, French).

Planning for CARIBE WAVE 21 took over 10 months and was coordinated by a task team led by Dr Elizabeth Vanacore of the University of Puerto Rico at Mayagüez, Department of Geology, Puerto Rico Seismic Network (PRSN) and facilitated by the US NWS Caribbean Tsunami Warning Program (CTWP). The Tsunamizone.org website was used for participant registration.

* Aruba, Bahamas, Barbados, Belize, Brazil, Colombia, Costa Rica, Cuba, Curacao, Dominica, Dominican Republic, France (Martinique, Guadeloupe, Guyane, 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, Trinidad and Tobago, United Kingdom (Anguilla, Bermuda, British Virgin Islands, Cayman Islands and Turks and Caicos), United States (Puerto Rico and the US Virgin Islands) and Venezuela (Bolivarian Republic of).

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 an extended officers meeting, the ICG/CARIBE-EWS recommended that Exercise CARIBE WAVE 21 take place on 11 March 2021, with two hypothetical tsunami scenarios. The first scenario simulates a tsunami generated by a magnitude 8.0 earthquake located along the Enriquillo-Plantain Garden Fault Zone (EPGFZ) off Jamaica, and the second scenario is generated by an 8.5 magnitude earthquake located along the Leeward Islands in the Northern Lesser Antilles.

Historical tsunami records from sources such as the National Oceanic and Atmospheric Administration's (NOAA) Centers for Environmental Information (NCEI) show that from 1530 to 2020 tsunamis from earthquake, landslide, and volcanic sources have affected the region. According to NCEI, in the past 500 years, at least 82 tsunamis have been observed and approximately 4,500 people have lost their lives from tsunamis in the Caribbean and adjacent regions. Since the most recent devastating tsunami of 1946, there has been an explosive population growth and influx of tourists along the Caribbean and Western Atlantic coasts increasing the tsunami vulnerability of the region (von Hillebrandt-Andrade, 2013).

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 tsunami 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 CARIBE WAVE 21 exercise provided simulated threat tsunami messages from the PTWC triggered by two hypothetical earthquakes: (i) 8.0 Mw with an epicenter at 18.2ºN, 75.3ºW located at the Enriquillo-Plantain Garden Fault Zone (EPGFZ) off Jamaica (Figure 1); and (ii) 8.5 Mw with an epicenter at 18.9ºN, 62.4ºW located along the Leeward Islands in the Northern Lesser Antilles (Figure 2).

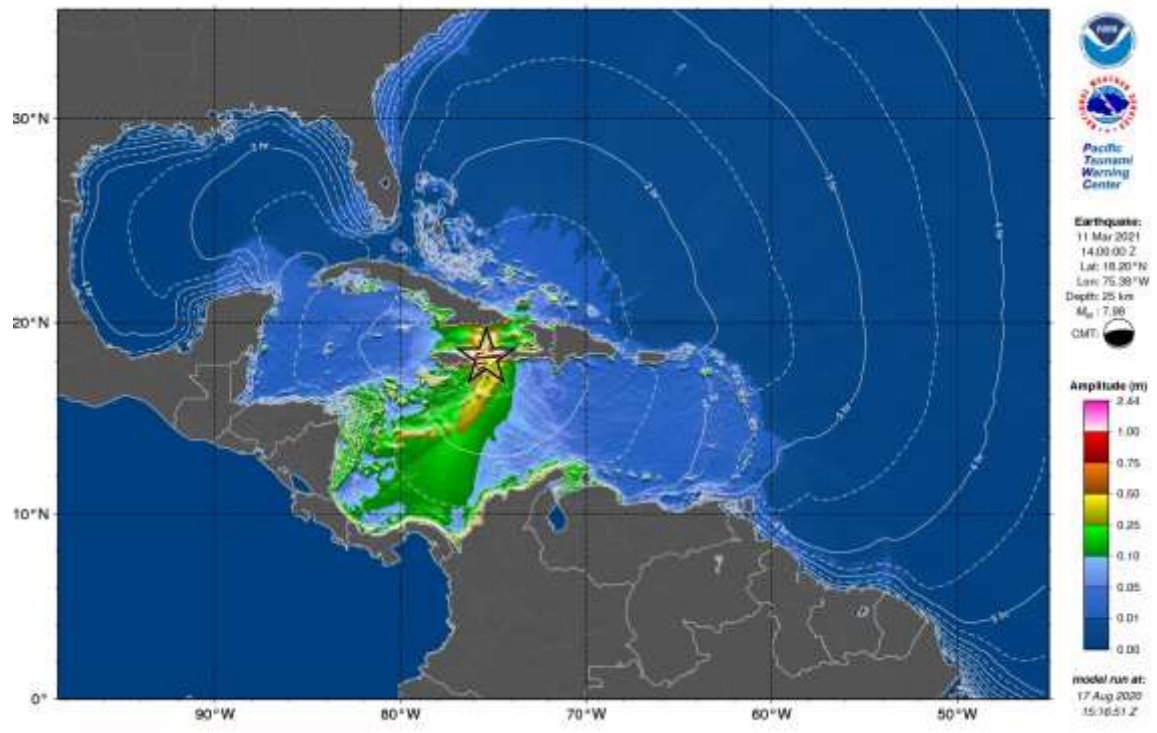

Figure 1. PTWC maximum deep-ocean amplitude map generated using RIFT for Jamaica scenario.

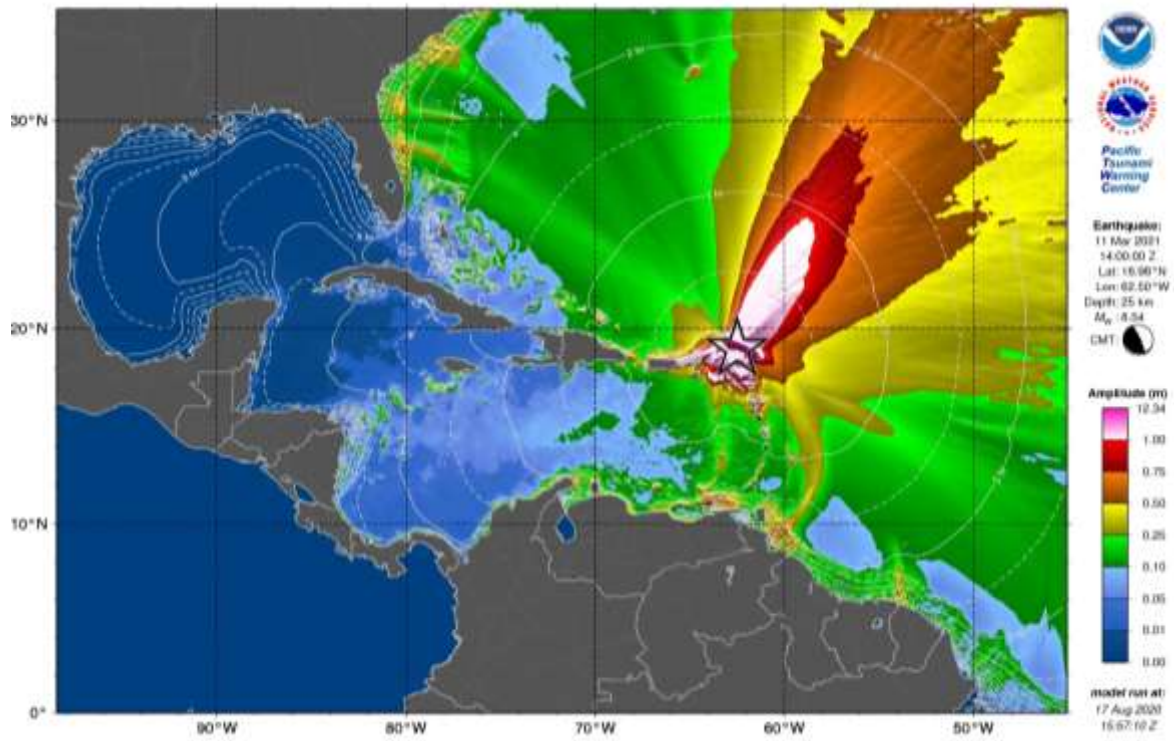

Figure 2**.** PTWC maximum deep-ocean amplitude map generated using RIFT for Northern Lesser Antilles scenario.

2. EXERCISE CONCEPT

2.1 PURPOSE

The purpose of the exercise was to improve Tsunami Warning System effectiveness in the Caribbean and adjacent regions. The exercise provided an opportunity for emergency management organizations 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 in case of 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 (EMO) was encouraged to participate.

2.2 OBJECTIVES AND GOALS

Each organization developed its objectives for the exercise depending on its level of involvement in the scenario. There were two principal overarching objectives for the exercise.

1. **Exercise and evaluate communications between Regional Tsunami Service Provider and Members States/Territories.**
    a. Validate the issuance of Tsunami products from the PTWC.
    b. Validate receipts of Tsunami products by CARIBE-EWS Tsunami Warning Focal Points (TWFPs) and/or National Tsunami Warning Centers (NTWCs).

2. **Evaluate the tsunami procedures and programs within Members States/Territories.**
    a. Validate readiness to respond to a tsunami.
    b. Validate the operational readiness of the TWFPs/NTWCs and/or the National Disaster Management Office (NDMO).
    c. Improve operational readiness. Before the exercise, ensure appropriate tools and response plan(s) have been developed, including public education materials.
    d. 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.
    e. Evaluate the status of the implementation of the pilot CARIBE-EWS Tsunami Ready recognition program.

ICG/CARIBE-EWS has established metrics to evaluate the goals of the exercise (Table 1). Only 95% of Member States and Territories submitted the Post-Exercise Survey, with 96% being satisfied with the exercise.

Goals	2016 Results	2017 Results	2018 Results	2019 Metrics	2019 Results	2020 Metrics	2020 Results	2021 Metrics	2021 Results
TWFP receive the dummy message	84%	95%	100%	100%	89%	100%	97%	100%	97%
Participation of Member States of ICG/CARIBE-EWS with designated focal warning point	100%	100%	97%	100%	100%	100%	92%	100%	98%
Community involvement (including agencies beyond TWFP)	73%	82%	77%	95%	66%	95%	38%	95%	56%
Number of participants*	332,812	679,985	643,403	+10%	793,353	+10%	4,622	+10%	333,518
Countries who participate submit exercise questionnaire	100%	100%	91%	100%	82%	100%	92%	100%	95%
Members State and territories are satisfied with exercise					82%	100%	76%	100%	96%

Table 1. Goals and Metrics. * As reported by Member States and Territories.

2.3 TYPE OF EXERCISES

The CARIBE WAVE 21 was planned for Caribbean countries to carry exercises at various scales of magnitudes and sophistication. In light of the implications due to the coronavirus emergency, it was up for Member States and territories to decide the type of exercise would be carried out. The CARIBE WAVE Task Team recommended countries to plan and execute the exercise accordingly by taking into consideration the CARIBE EWS COVID-19 guidelines (English, French). Communication tests were carried out to validate the issuance and receipt of the messages distributed by the Pacific Tsunami Warning Center (PTWC), the Regional Tsunami Service Provider, and evaluations of the tsunami procedures and programs within Member States and Territories. Several of the National and local Offices of Emergency Management (OEM) were able to extend the exercise down to the level of testing local notification systems such as the Emergency Alert System (EAS), sirens and loudspeakers.

According to the Member States, the number of participants in the exercise was 333,518 people throughout the Caribbean and adjacent regions. The participants in the tenth annual regional tsunami exercise hailed from forty-seven out of forty-eight Member States and territories. It represented a participation rate of 98% 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). This level of participation represents the high enthusiasm from the CARIBE-EWS Members States to participate despite the trying situation of the COVID-19 pandemic.

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 (SOPs). The reported exercises included a variety of activities including testing communication systems, performing tabletop exercises, conducting seminars and drills (Figure 3). Additionally, for the first time the Task Team organized a post-exercise “hot wash” webinar to permit Member States and Territories to discuss and provide feedback on the

exercise in an open forum. The participants recommended that a hot wash be an added activity to the exercise.

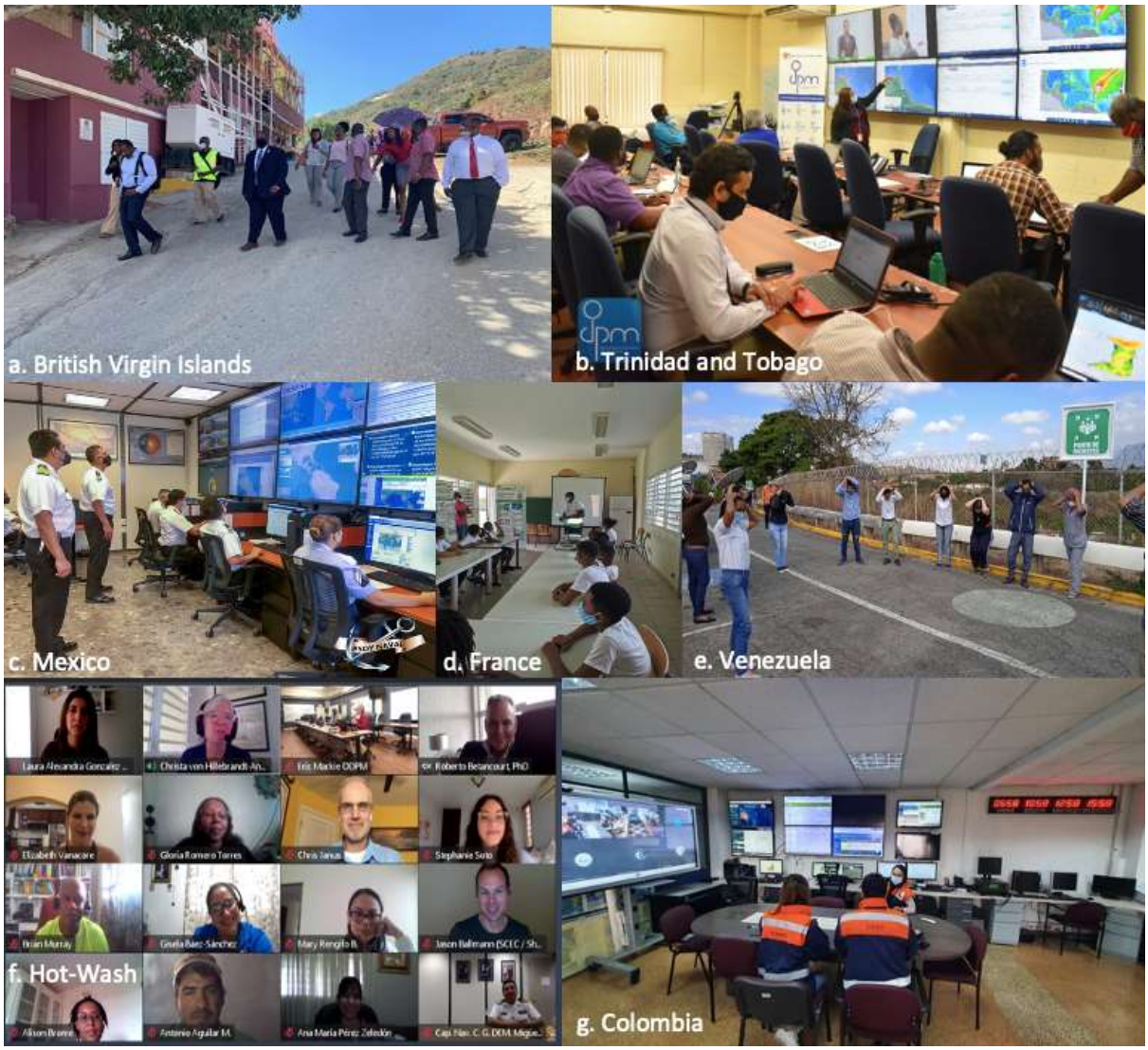

Figure 3. Participation of the exercise, CARIBE WAVE 21: British Virgin Islands (a), Trinidad and Tobago (b), Mexico (c), Martinique, France (d), Venezuela (e), CW21 Hot-Wash (f), and Colombia (g).

3. EXERCISE OUTLINE

3.1 GENERAL

The tsunami messages that were issued for this exercise by the PTWC were based on two hypothetical earthquakes (Figure 4) with the following hypocenter parameters:

Jamaica Earthquake Scenario:

Origin Time	14:00:00 UTC March 11, 2021
Latitude	18.2ºN
Longitude	75.3ºW
Magnitude	8.0 – M_w
Depth	25 km

Northern Lesser Antilles Earthquake Scenario:

Origin Time	14:00:00 UTC March 11, 2021
Latitude	18.9°N
Longitude	62.4°W
Magnitude	8.5 – M_w
Depth	25 km

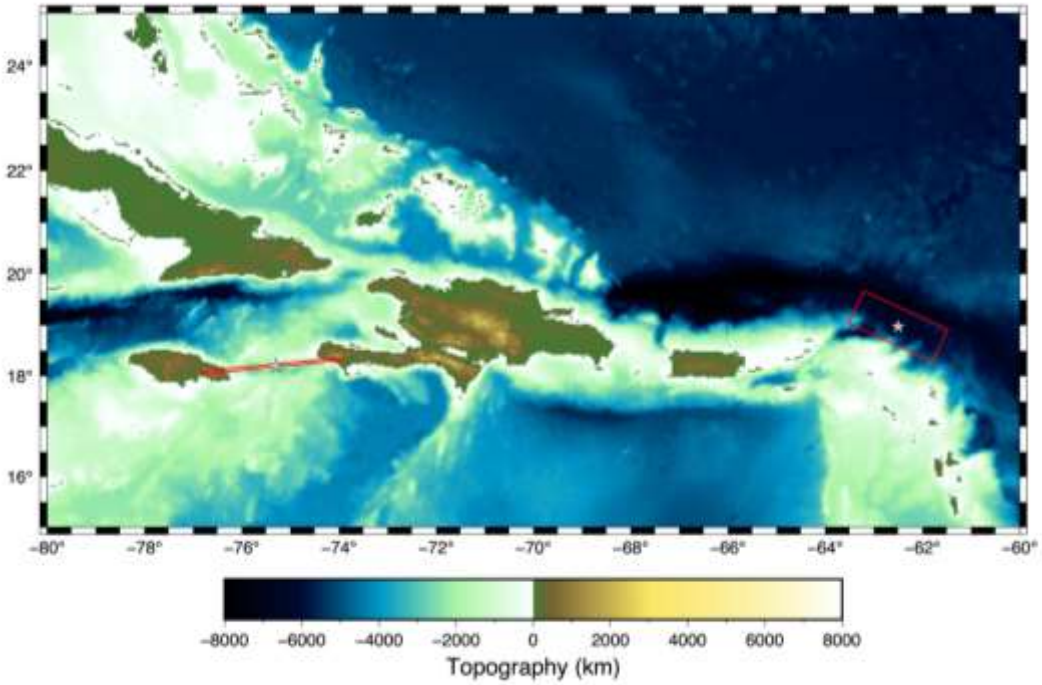

Figure 4. Map of the CARIBE WAVE 21 scenarios. Stars indicate epicentral locations and the red boxes indicate the map view of the ruptured fault segments. The figure is underlain by etopo1 model of Amante and Eakins (2009). This figure was generated using The Generic Mapping Tool (GMT) (Wessel et al., 2013).

Messages Issued by the PTWC

The PTWC issued (25) international simulated messages for CARIBE WAVE 21. The first tsunami threat message for the Jamaica and Northern Lesser Antilles was based on the earthquake magnitude and location, and the tsunami travel times. While as of the third messages were based on simulated tsunami wave forecast, rather than seismic information. Tsunami threat forecast indicated the levels of threat that have been forecast and to which the countries or places they apply. The levels are tsunami heights of 0.3-1 meters, 1-3 meters, and greater than 3 meters above the normal tide levels are determined. The threats were updated usually within an hour.

Member States were required to select one scenario by February 26 for the 2021 exercise. Those who did not select a scenario, the organizers decided for which scenario the PTWC would send the products. All simulated products (text and graphical) were disseminated through email to the corresponding TWFPs and NTWCs and were made available in the Exercise Handbook (Volume of this publication). Any 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 11 March 2021.

3.2 MASTER SCHEDULE (EXERCISE SCRIPT)

CARIBE-EWS Tsunami Service Provider (PTWC) issued the initial dummy message for the two scenarios on March 11, 2021 at 1400 UTC. This message was used 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, GNC-A, Email, Fax, and AWIPS (Advanced Weather Interactive Processing System), using header IDs WECA41 PHEB/TSUCAX. All simulated products (text and graphical) were disseminated only thru email to TWFPs and NTWCs. Twelve (12) threat messages were issued for the Jamaica scenario, and thirteenth (13) for the Northern Lesser Antilles scenario. The graphical enhanced products were included in the third threat message for both Jamaica and Northern Lesser Antilles scenario. As in past years, the most common methods to receive the Dummy message were the Email and Fax (Figure 5).

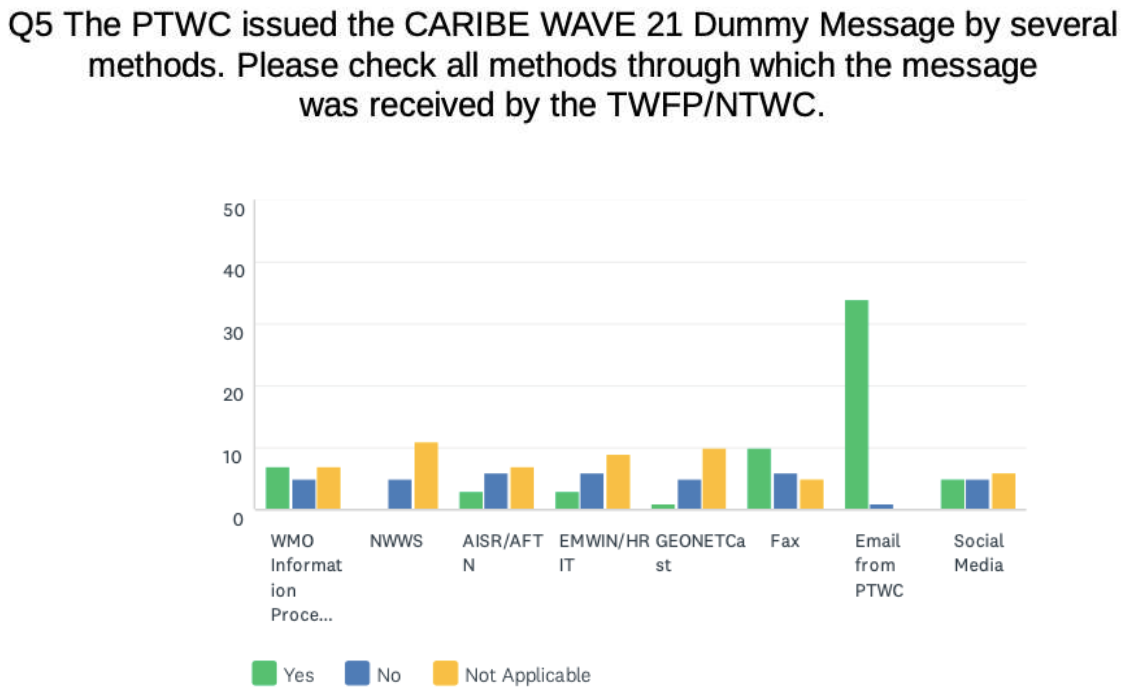

Figure 5. Methods that the CARIBE-EWS TWFPs/NTWCs used to receive the Dummy message by the PTWC.

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 REGISTRATION PROCEDURE

As for past exercises, the CARIBE-EWS teamed up with TsunamiZone.org for online registration (Figure 6). 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 three major categories:

1. Myself and/or my family,
2. My school, district, college/university, or childcare center, and
3. My organization, department, or agency (including TNCs. TWFPs and NTWCs). EMOs were encouraged to promote this registration system.

Most people registered directly on the TsunamiZone.org which is an open registration system available during the whole year. As of 23 April 2021, 347,865 people had registered (Table 2). Nevertheless, according to Member States who answered the post-exercise survey, the estimated number of people actually participating were approximately 333,518 (Table 3).

Figure 6. Registration by categories and Country
for the CARIBE WAVE 21 Regional Tsunami Exercise.

Category	Number of Participants
Individuals/Families	2,630
Childcare and Pre-Schools	2,247
K-12 Schools and Districts	115,786
Colleges and Universities	18,410
Local Government	33,577
State Government	127,409
Federal/National Government*	7,805
Businesses	1,667
Hotels and Other Lodgings	505
Healthcare	9,326
Senior Facilities/Communities	466
Disability/AFN Organizations	216

* This includes TWFPs and TNCs

Category	Number of Participants
Non-Profit Organizations	5,717
Neighborhood Groups	683
Preparedness Organizations	19,033
Faith-based Organizations	52
Museums, Libraries, Parks, etc.	737
Volunteer/Service Clubs	248
Youth Organizations	5
Animal Shelter/Service Providers	2
Agriculture/Livestock	160
Volunteer Radio Groups	466
Science/Engineering Organizations	332
Media Organizations	346
Other	40
Total	**347,865**

Table 2. List of registrants and participants by Categories on TsunamiZone.org in the Caribbean (as of 04/19/2021)

Country	Participants according to Member States	Participants according to Tsunami Zone
Antigua and Barbuda	65*	65
Bahamas	7*	7
Barbados	97	101
Belize	20*	20
Brazil	11*	11
Colombia	70	57
Costa Rica	2	15
Cuba	250	170
Dominica	20	10
Dominican Republic	200	206
France (Martinique, Guadeloupe, Guyane, St. Barthelemy, St. Martin)	85,291	85,291
Grenada	7,603	7,605

Country		Participants according to Member States	Participants according to Tsunami Zone
Guatemala		0*	0
Guyana		10	8
Haiti		100	42
Honduras		10	0
Jamaica		148	632
Mexico		560	250
Netherlands	**Aruba**	1,100*	10,280
	Bonaire, Saba, Sint Eustatius	20	23
	Curacao	50	122
	Sint Maarten	100	75
Nicaragua		90	100
Panama		12	644
Saint Kitts and Nevis		6,000	6,000
Saint Lucia		228	228
Saint Vincent and the Grenadines		15	27
Suriname		0*	0
Trinidad and Tobago		346*	346
United Kingdom	**Anguilla**	1,250 *	1,250
	Bermuda	50	220
	British Virgin Islands	1,184	14
	Cayman Islands	3,888	3,888
	Montserrat	0*	0
	Turks and Caicos	78*	78
United States	**Puerto Rico**	94,194	94,194
	US Virgin Island	4,000	3,375
Venezuela		132,389	132,582
TOTAL		**339,458**	**347,865**

Table 3. List of participants by Country/Territory (as of 04/19/2021)
**Number taken from TsunamiZone.org for cases where countries did not report number of participants in survey*.

3.5 STATUS OF SEA LEVEL STATIONS DURING EXERCISE

An analysis of sea level stations status was carried out by the NOAA Caribbean Tsunami Warning Program (CTWP) as part of the CARIBE WAVE 21 Regional Tsunami Exercise. This allowed the CTWP to analyze the availability of sea level data. The PTWC provided simulated forecasted maximum wave heights for 50 CARIBE-EWS stations in the simulated bulletins. Only about 60% of these sea level stations were online on the IOC Sea Level facility during the exercise period (Figures 7 and 8). Similarly, the Tide Tool system used by many Tsunami Warning Centers had around 46% of stations operational, this is much less than the 76% data availability in CARIBE WAVE 2020 (Figures 10 and 11). All of the 7 DART stations were not streaming data in the Caribbean/Gulf and Atlantic thru the National Buoy Center during the day of the exercise (Figure 12).

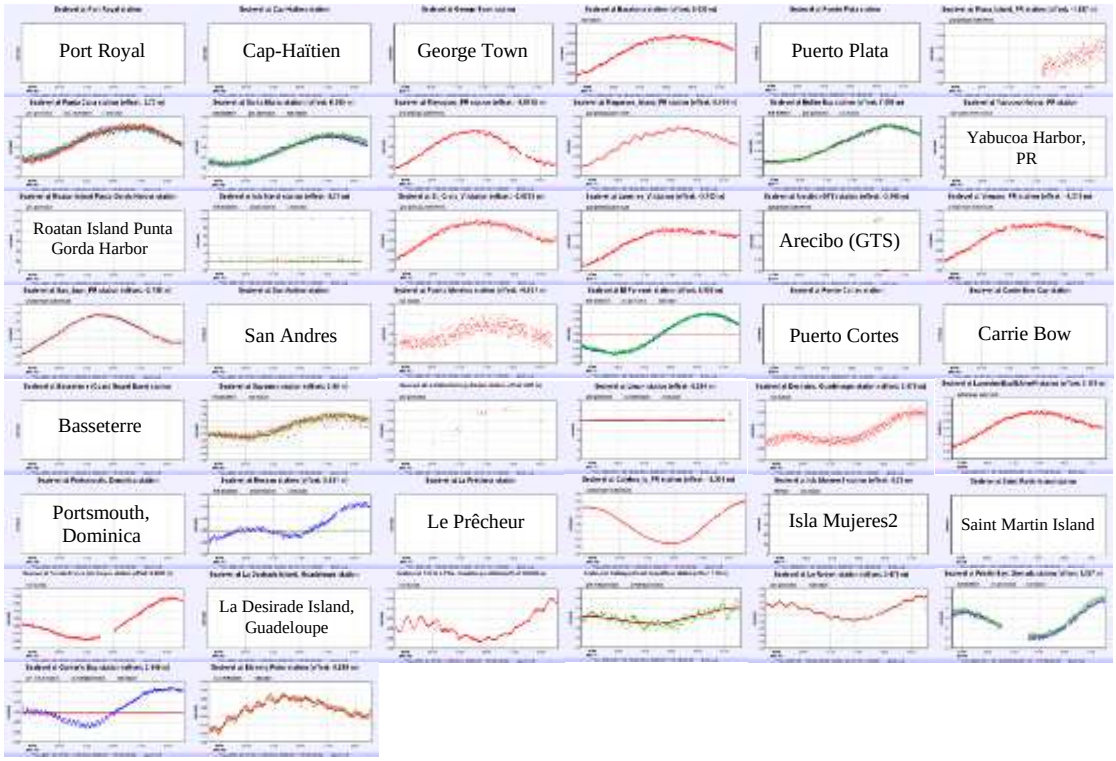

Figure 7. Forecast of maximum wave heights for the Jamaica scenario from 44 CARIBE-EWS coastal sea level stations during the Caribe Wave exercise. Stations for which the name of the station is provided, and not the wave form, are stations that had no data on the IOC Sea Level Monitoring Facility.

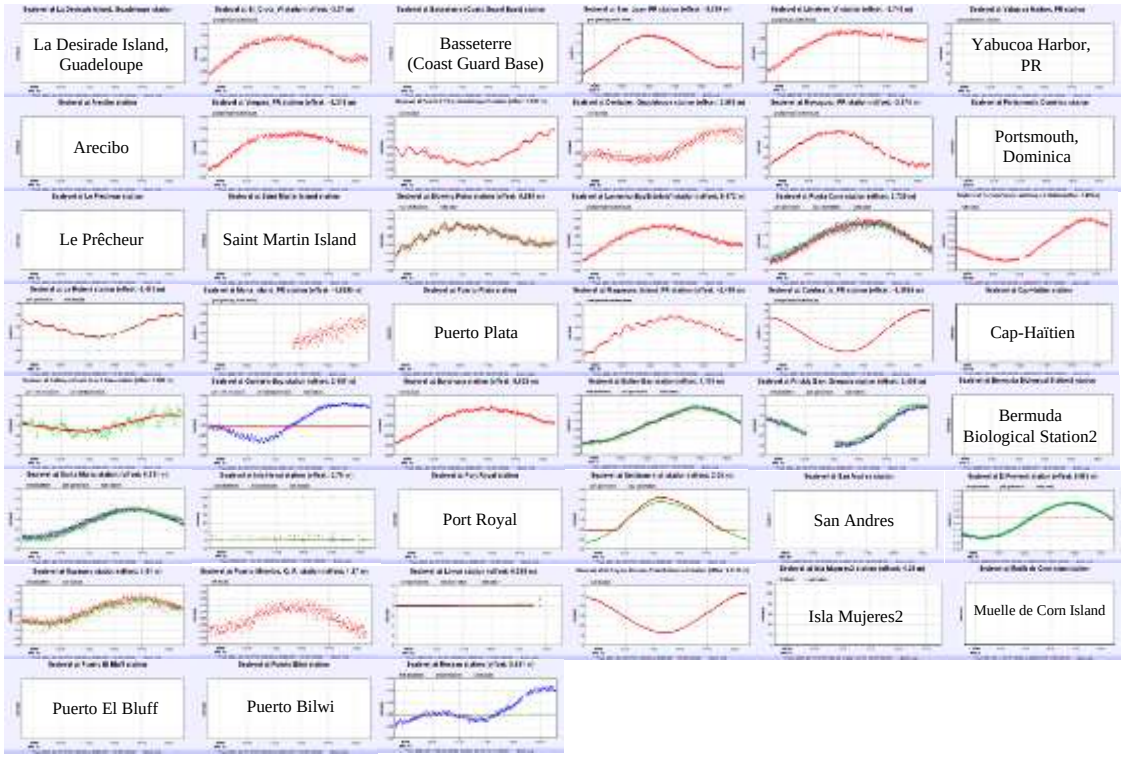

Figure 8. Forecast of maximum wave heights for the Northern Lesser Antilles scenario from 45 CARIBE-EWS coastal sea level stations during the Caribe Wave exercise. Stations for which the name of the station is provided, and not the wave form, are stations that had no data on the IOC Sea Level Monitoring Facility.

Figure 9. Screenshot showing IOC Sea Level facilities operating during the CARIBE WAVE 21 exercise. In green are stations for which data were available, red dots are for station for which there were no data.

3.6 RESOURCES

Although Emergency Management Organizations (EMOs) had advance notice of the exercise and some elected to set up a special dedicated shift to allow normal core business to continue uninterrupted, it was suggested that realistic resource levels be deployed in order to reflect

some of the issues that are likely to be faced in a real event. Considering the pandemic, agencies were requested to adjust the exercise to their best convenience.

This year Elizabeth Vanacore was the Exercise Chair while Alberto Lopez, Ivan Wong, Matt Hornback and Richard D Koehler were the scientific experts that helped in the determination of the Jamaica scenario; Alberto Lopez was the scientific expert for the Northern Lesser Antilles scenario which was based upon the outcome of a recent experts meeting in the region. The CTWP coordinated the exercise for CARIBE-EWS.

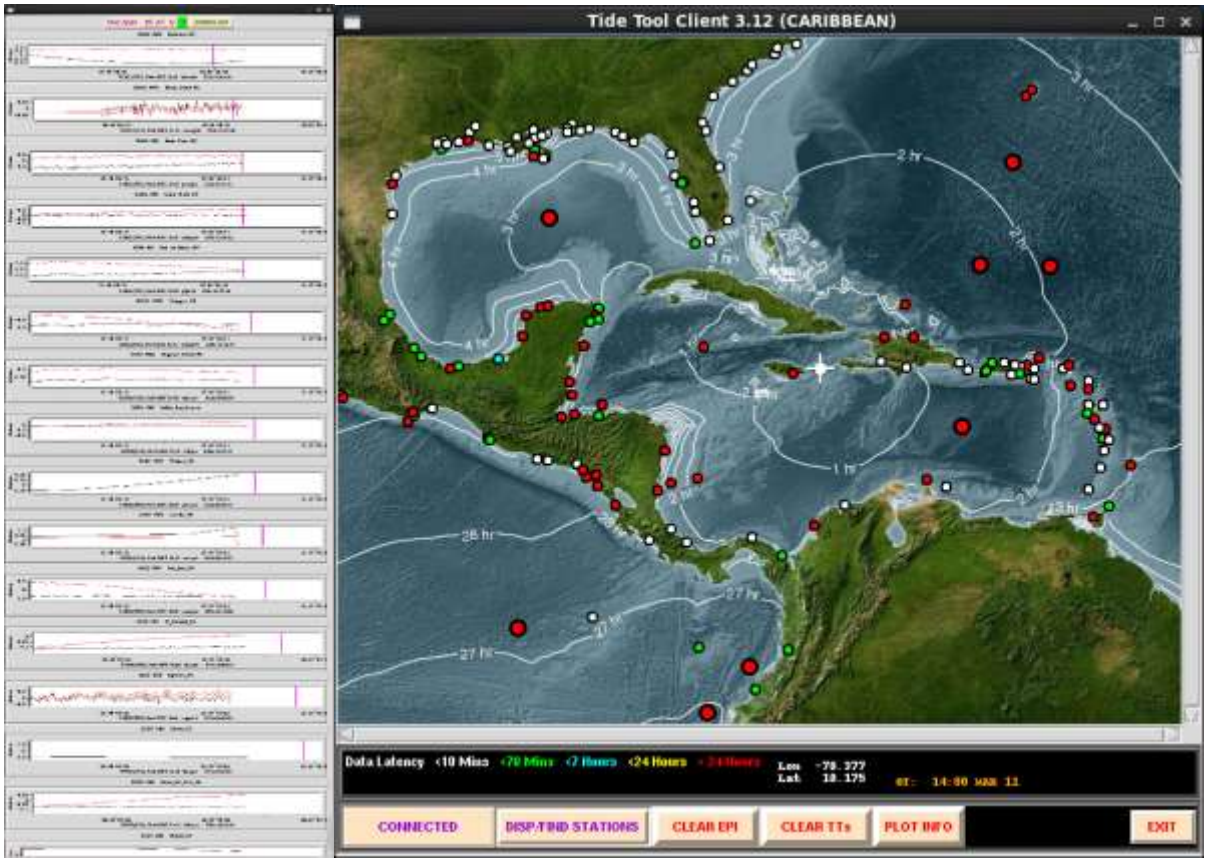

Figure 10. Screenshot from Tide Tool for the CARIBE WAVE 21 Jamaica Scenario. Tide Tool includes both coastal gauges and DARTs. In White and Green are operational stations, in red are stations with no data over the past 24 hours (non-operational). The Isochrons represent the travel time from the source of the simulated tsunami from. The Strip Chart to the left includes the marigrams from the closest 15 stations. The magenta stripe marks the estimated time of arrival.

Figure 11. Screenshot from Tide Tool for the CARIBE WAVE 21 Northern Lesser Antilles Scenario. Tide Tool includes both coastal gauges and DARTs. In White and Green are operational stations, in red are stations with no data over the past 24 hours (non-operational). The Isochrons represent the travel time from the source of the simulated tsunami from. The Strip Chart to the left includes the marigrams from the closest 15 stations. The magenta stripe marks the estimated time of arrival.

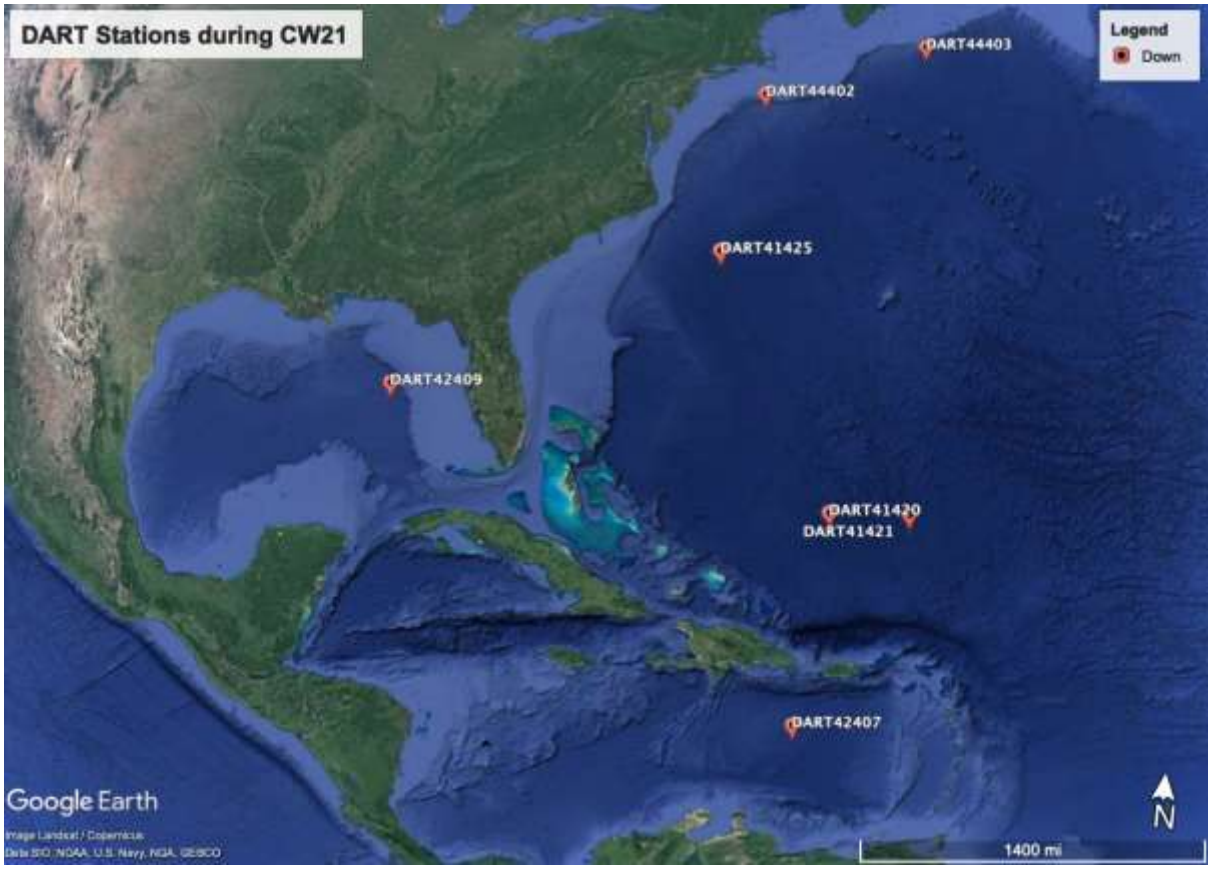

Figure 12. Map of operational and non-operational status of the DART's on March 11, 2021.

3.7 MEDIA ARRANGEMENTS

One advantage in conducting exercises is that it provides a venue to promote tsunami awareness. The exercise offers an opportunity to collaborate with the media and disseminate more broadly information on the warning system. The CARIBE-EWS Member States and Territories indicated that about 33% of the news media participated and covered the exercise. The hashtag tracker Brand24 was used to monitor #CaribeWave and #CaribeWave21 from February 21 to March 17. Its data resulted in over 300 mentions on social media outlets and posts reaching over 2 million people worldwide (Figure 13). Emergency management agencies from countries such as Barbados, Grenada, and St. Kitts and Nevis informed citizens through online article publications and social media posts that their country would participate in the exercise on March 11. The National Weather Service San Juan Forecast Office and the Caribbean Tsunami Warning Program, as well as the Puerto Rico Seismic Network also published informative posts related to tsunami awareness in preparation for CARIBE WAVE.

During the exercise, text messages and tweets about the start of the exercise were displayed on PTWC and CTWP accounts (Figure 14).

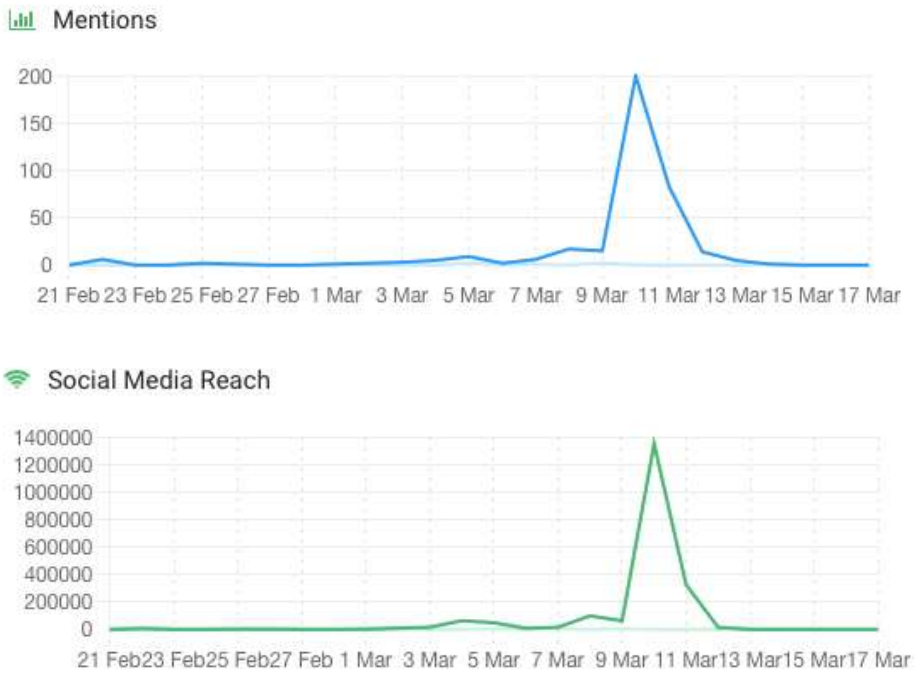

Figure 13. Graphs showing the #CaribeWave and #CaribeWave21 trending between the 21st of February and 17th of March 2021.

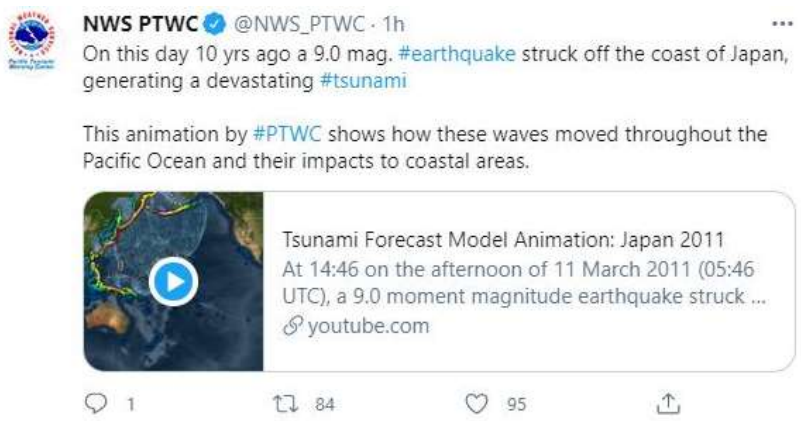

Figure 14. Twitter post about the CARIBE Wave 21 exercise from NWS PTWC's account.

3.8 POST-EXERCISE EVALUATION

All participating countries were requested to provide feedback on the exercise through a survey. The survey was reduced to reflect the decision and other priorities countries may have considering the COVID-19. This feedback assists the ICG/CARIBE-EWS in the evaluation of CARIBE WAVE 21 and the development of subsequent exercises and helps response agencies document lessons learned. The survey contained 27 questions and was conducted by the IOC of UNESCO using the Survey Monkey service. Thirty-six (36) surveys were completed representing the feedback from 95% of the Member States and Territories.*

Considering the circumstances of the pandemic, the survey was available from the start of the exercise on March 11 and extended through March 31. Overall, the results indicated that the Dummy (Start of Exercise) message was received by 35 Member States, representing 97% of the CARIBE-EWS Member States and Territories. There was a strong dependency on Email and Fax for the reception of products from the PTWC. The message was received by most countries within the first 1-2 minutes, and few countries reported delays. Despite COVID-19, 56% of the Member States indicated that the TWFP/NTWC issued messages to relevant in country agencies. The exercise planning went well under extenuating circumstances, resulting in a 96% of satisfaction of Member States and Territories, and a total participation of 333,518 people from the Caribbean. The questions of the survey as well as the answers and comments are contained in the Supplement available at the caribewave.info website.

This evaluation contains valuable information and gives to the ICG/CARIBE-EWS group insights to address the objectives of the exercise. **The results for the status of the implementation of the pilot CARIBE-EWS Tsunami Ready recognition project indicated that 87% of the countries are interested in implementing the program and 54% of these are already implementing it with 319 as total number of target communities to be recognized as Tsunami Ready** (Table 4).

In addition, the survey provided the Member States an opportunity to provide additional feedback on the exercise (Table 5). The comments received confirm how COVID-19 impacted the scope of the national and local exercises.

Country	Already Implementing	Interested in Implementing	TsunamiReady® or Tsunami Ready Communities (as reported by Member States)	TsunamiReady® or Tsunami Ready Communities (IOC Records For CARIBE EWS)	Target Number
Antigua and Barbuda	Yes	-	-	1	-
Bahamas	Yes	-	10	0	22
Barbados	Yes	-	8	1	50
Belize	Yes	-	0	0	1
Brazil	No	Yes	0	0	0

* Countries and Territories answering the post-exercise survey: Aruba, Anguilla, Barbados, Bahamas, Belize, Brazil, Colombia, Costa Rica, Cuba, Curacao, Dominica, Dominican Republic, France, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Netherlands (Bonaire, Saba and Saint Eustatius), Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Sint Maarten, Trinidad and Tobago, Turks and Caicos, United Kingdom (Bermuda, British Virgin Islands, Cayman Islands, Montserrat), United States (Puerto Rico and the US Virgin Islands) and Venezuela.

Country	Already Implementing	Interested in Implementing	TsunamiReady® or Tsunami Ready Communities (as reported by Member States)	TsunamiReady® or Tsunami Ready Communities (IOC Records For CARIBE EWS)	Target Number
Colombia	No	Yes	0	0	0
Costa Rica	Yes	-	8	0	15
Cuba	No	Yes	0	0	2
Dominica	No	Yes	-	0	-
Dominican Republic	Yes	-	0	0	2
France	No	Yes	-	0	-
Grenada	Yes	-	4	2	-
Guatemala	No	Yes	2	0	17
Guyana	No	Yes	-	0	-
Haiti	No	Yes	1	1	20
Honduras	Yes	-	4	2	1
Jamaica	Yes	-	0	0	55
Mexico	No	Yes	0	0	10
NL- Aruba	Yes	-	0	0	-
NL- Bonaire, Saba, and Sint Eustatius	No	Yes	0	0	3
NL- Curacao	No	Yes	0	0	-
NL- Sint Maarten	No	Yes	0	0	1
Nicaragua	Yes	-	2	2	3
Panama	Yes	-	6	0	12
Saint Kitts and Nevis	Yes	-	-	1	1
Saint Lucia	No	Yes	0	0	4
Saint Vincent and the Grenadines	Yes	-	0	1	8
Trinidad and Tobago	Yes	-	1	1	0

Country	Already Implementing	Interested in Implementing	TsunamiReady® or Tsunami Ready Communities (as reported by Member States)	TsunamiReady® or Tsunami Ready Communities (IOC Records For CARIBE EWS)	Target Number
UK- Anguilla	Yes	-	4	1	-
UK- Bermuda	No	No	-	0	-
UK- British Virgin Islands	Yes	-	1	1	1
UK- Cayman Islands	No	No	-	0	-
UK- Montserrat	Yes	-	2	0	4
UK- Turks and Caicos	-	-	-	0	-
USA- Puerto Rico	Yes	-	46	46	46
USA- US Virgin Islands	Yes	-	3	3	4
Venezuela	No	Yes	0	0	60
TOTAL	19 YES	14 INTERESTED	100	63	342

Table 4. Status of Implementation of the Pilot CARIBE EWS Tsunami Ready Recognition Program.

Table 5 below provides general statements on Caribe Wave 21 Tsunami Exercise experience from countries that participated.

Country	Exercise Caribe Wave 21 General Statements
Barbados	The communication aspect of the Caribe Wave exercise was a general success apart from a few misunderstandings early in the exercise which were resolved. The COVID-19 pandemic presented the opportunity for the island to solely test its telecommunications capabilities. This process was evaluated by qualified and experienced radio telecommunication specialist who concluded that the exercise was a success based on markers such as the span and rate of message transmission, the quality of the message relayed (radio etiquette, precise and clear information transmission, etc.). Caribe Wave 2021 provided a basis for evaluation and teaching strategy formulation where participants were able to be gauged on areas for improvement. The exercise also allowed for individuals who were new to the disaster management arena to be baptized with relation to the procedures, practices and the general atmosphere with regards to disaster response. The general consensus among the District Emergency Organizations who

Country	Exercise Caribe Wave 21 General Statements
	were able to test their ability to operate in a zone environment was that the experience was a great one, but they only wished the exercise lasted longer to facilitate more role play with regards to the plethora of scenarios they can encounter. The DEOs also indicated that they were intently looking forward to participation in similar exercises in the future. The Caribe Wave Exercise 2021 served nor only as a practice run of procedures in case of a Tsunami but also served in promoting team building, confidence boosting of persons new to disaster management arena, promotion of cross agency collaboration and network building, encouraged recruitment and retention of members of the District Emergency Organizations but most importantly it served as a measure where through practical exercises such as these we are able to formulate programmes based on the existing apparatus in place to improve and increase training programmes, procure additional equipment and fine tune any other minor areas. In conclusion, the programme was marked a success as the generated alerts were efficiently and effectively dispersed via all available forms of telecommunication.
Brazil	It was important to restart the communication between Nacional Contact and Focal Point.
Colombia	Despite being in a pandemic, the exercise was successfully carried out, testing the protocols and procedures established at the national and local levels, as well as the use of different means of communication. It is necessary to continue working with the community in order to link their participation through evacuations in coastal areas in future exercises.
Costa Rica	We just received the emails and one phone call from CNE saying they received the Dummy message.
Cuba	All links of the National Tsunami Warning System were trained, in some cases virtually due to the measure applied for the pandemic. The experiences obtained were immediately applied to the improvement of the risk studies and the tsunami warning.
Dominica	In general, the planning and execution of the activities for Caribe Wave went well. Dominica chose to include an earthquake drill in schools in the activities for Caribe Wave which would have been followed by an evacuation for tsunami. However, given COVID-19 pandemic this was scaled back to simply discussing tsunami safety protocols and safety measures. Dominica also used the opportunity to conduct an Emergency Communication exercise to test communication capacity among national first responders and other key stakeholders. This allowed the disaster system to identify weaknesses that should be addressed particularly as we approach the 2021 hurricane season.
Dominican Republic	The scenario selected by the Dominican Republic was that of the Northern Lesser Antilles; all planning was in accordance with what was established in the exercise manual. We understand that it was a good exercise within the world reality.
France	Messaging with the communication media we use is correct but other tools will need to be explored to increase resilience.
Grenada	Participation in CARIBE WAVE 21 was another success. We had excellent stakeholder participation including some schools. There were areas identified for improvements within the tsunami protocol which will be addressed going forward.

Country	Exercise Caribe Wave 21 General Statements
Guatemala	The exercise will be replicated involving the national risk management office, after improvements of our internal protocols, currently under discussion, are finished.
Guyana	This year the COVID pandemic prevented us from having the usual multi-agency exercise. Additionally, the office has a few new forecasters, so a decision was made to walk them through the protocol using the different products. The reception of the initial message though the FAX, e-mail and CISN were covered. Next the Tsunami Travel Time tool was used with the initial information to determine the possible time of arrival if a wave were to be generated. As the other messages and products were made available, their uses were discussed.
Haiti	Haiti has realized this exercise. For Caribe Wave 2021, Haiti expected to make a better exercise. Unfortunately, it was impossible to do it because of the bad political and insecure situation.
Jamaica	The exercise was successful. Scenario presented a good basis for analysis of capacities (local/national), communication gaps, and usefulness of Warning Protocols. Exercise also served to re-orient/orient official on Warning Protocols as well as need for agency/organizational Tsunami Warning/Response Protocols.
Mexico	The plans and procedures were put into practice, including the measurements against COVID-19, which is why it is essential to continue carrying out this type of exercise.
Nicaragua	Although this exercise was atypical, due to the problems of the COVID 19 pandemic, the high levels of willingness and participation of the member countries through online communication allowed for significant progress, which is highly commendable.
NL - Bonaire, Saba, and Sint Eustatius	In this case warning time between message and arrival of the wave was very short, meaning that as TWFP we expected local authorities to start procedures based on having felt the EQ. By the time we managed to reach them by phone (+20 min) it was already too late for Saba/St. Eustatius. It turned out mobile Saba numbers could not be reached from mainland NL, due to an issue with the provider. We are investigating what causes this problem. In the meantime, WhatsApp calls and calls to fixed numbers function properly. Reaching the right people is challenging because cellular reception is not good everywhere on the islands, meaning that sometimes mobiles do not work, and fixed lines need to be called. We will discuss improved communication with local governments. By introducing for example, a dedicated hot-line phone that they can forward to whatever phone they like.
NL - Curacao	This year we participated virtually to the CARIBE WAVE 21 Tsunami Exercise. This is an important exercise to make the population more aware of the dangers of a tsunami in the Caribbean. Curacao was in a lockdown and this impacted the way we participated to this exercise.
NL - Sint Maarten	We combined the Caribe Wave 21 exercise with an extensive ongoing training program which is ongoing with support from the Netherlands. We divided the disaster management teams in 6 groups. They were updated on their specific responsibilities within the disaster management system. Each session included a tabletop exercise using the Caribe Wave scenario. This

Country	Exercise Caribe Wave 21 General Statements
	was done during the entire week, so the timelines of the official exercise were not used.
Panama	The CARIBE WAVE 21 Tsunami Exercise provided a good experience, even it was a desktop event, because of the communication proof and results. In my personal opinion, future seismic parameters (as magnitude) should be selected considering historical tsunami data and geographical seismic zones. The magnitude of 8.0 Mw for Jamaica scenario was a bit overestimated.
Saint Kitts and Nevis	Virtual exercise provided an opportunity to capture decision makers and bring attention to the importance of their roles during a potential Tsunami impact. The testing of the cognitive skills brought a different dimension to the annual exercise that can be used to host more frequent tabletop exercises and target various communities and agency without utilizing or mobilizing a heavy resource pool. It also gave us the opportunity to be able to marry the cognitive and physical response. This strengthens monitoring and evaluation of the procedures and policies.
Saint Lucia	For CARIBE WAVE 21, and due to COVID-19 restrictions on mass gatherings, social distancing and other safety protocols, Saint Lucia decided to test their emergency early warning systems by triggering its sirens in three coastal communities, namely Anse La Raye, Canaries and Castries. Saint Lucia's exercise scenario was based on the Northern Antilles scenario. In preparation for the exercise, Saint Lucia participated in the two webinars, on January 26th and February 23rd. Saint Lucia's National Tsunami warning focal point, the St Lucia Met Service, received the dummy message from the PTWC at 14:04 UTC. However, the Tsunami Warning Center, the National Disaster Office did not receive the message. Additional, Saint Lucia has expressed an interest in implementing a Tsunami Ready programme to strengthen the tsunami preparedness and response in our vulnerable coastal communities. Formal confirmation has been received and the necessary infrastructure is being put into place to begin the Tsunami Ready journey.
Saint Vincent and the Grenadines	This year's participation was limited due to the ongoing volcanic activity at the La Soufriere volcano. We however were able to participate along with the Met service in the receipt of the PTWC messages and familiarize ourselves with the format.
Trinidad and Tobago	From the perspective of the TWFP, the exercise was a success for the most part, as messages were received on time and in good order. There was not much interaction with the NTWC beside communicating the PTWC messages to them and confirming receipt. Other agencies would have carried out their own exercises such as radio checks and outreach activities in a few communities.
UK - Bermuda	Overall, the CARIBE WAVE 21 exercise went well as a communications test. Although a review of our SOPs by BWS Management may be useful. Duty staff performed their functions well as outlined in the SOPs. In the interest of improving response times for every aspect of tsunami communication, it would be good to have more pre-canned messaging templates 'ready to go' for real events (and also for exercises). This will be considered in our review of SOPs in April. Also, it is noted that some of the messages that are not included in SOPs (especially with respect to social

Country	Exercise Caribe Wave 21 General Statements
	media) were sent out as a 'good idea' afterthought by BWS Management; social media messages should be included in the collection of templates. As a general note, we (Bermuda) need to develop more quick and pre-canned decision-making procedures for tsunamis. There remain open questions about what decisions would/could be made if a short fuse event occurs, especially in the middle of the night. Ongoing efforts to educate key decision makers about the real threats and uncertainties for natural hazards will be central to this effort.
UK - British Virgin Islands	This exercise was a bit different since we had to use COVID-19 protocols. This included practicing social distancing, wearing masks and using hand sanitizer. The stress of COVID-19 created a bit of fear in persons and they did not want to evacuate even though it was an exercise.
UK- Cayman Islands	We engaged the schools and asked them to test their response procedures. We also rested our emergency notification system, the radio interrupt and the emergency app which is about to launch.
USA - Puerto Rico	The communication at PREMB were excellent, we tested every communication system available to receive the alerts and disseminate them to the Municipal Emergency Management Office. The 46 TsunamiReady Communities and the TsunamiReady Supporter Agencies participated. 28 municipalities test their outdoor sirens, some of those sirens which were damaged after the hurricane Maria. Other communities painted evacuation routes on the streets (Toa Baja, Lajas, and Barceloneta) or on murals in the coastal area (Ponce). On the other hand, PRSN tested multiple communication methods with emergency management agencies in our area of responsibility (Puerto Rico and Virgin Islands Region). Starting on February 11, 2021, pre-exercise communication test was conducted to promote CARIBE WAVE Exercise in the Puerto Rico and Virgin Islands Region among emergency managers and the public. These tests were issued on February 11, March 1, March 7, and March 10, by all communication lines available in PRSN (dedicated telephones, emails, fax, text message, RSS, and social media). On March 11, 2021, we issued a total of 16 messages during CARIBE WAVE 2-21 Communication Exercise. The first one was a reminder of the exercise at 9:00 a.m. (Puerto Rico Local Time) to social media. The first PRSN bulletin was issued at 10:00 a.m. through the RSS, FAX, email service lists, SMS service list, Ring Down, Private Line Phone Call (Emergency Managers of Puerto Rico, Virgin Islands, and the Dominican Republic), Automatic Phone Call service list, PRSN web page, and social media, announcing the beginning of the exercise. In addition, 13 Official PRSN Bulletins were issued with Tsunami Warning, Advisory, and Cancellation information (in Spanish and English), as issued by the PTWC in domestic products for Puerto Rico and the Virgin Islands. All bulletins (from #01 to #13) were disseminated by NMEAD Radio Frequency, dedicated telephone lines, emails, fax, RSS, text messages, automatic calls, and social media. In general, the dissemination of the automatic products to emergency agencies in our region took place at approximate times of 0 to 5 minutes. Agency-to-Agency (a total of 8 emergency agencies) calls through the dedicated telephones lines were completed, on average, within 8 minutes. For this exercise, (only for Puerto Rico) the EAS system was activated in coordination with the Puerto Rico Emergency Management Bureau, National Weather Service (San Juan), Puerto Rico Broadcast Association, and Puerto Rico EAS Committee, through the following communication means: radio, T.V., cable, and NOAA weather radio. The real alert code tsunamis (TWS) was issued during the exercise at 10:07 a.m. on March 11, 2021, by the National Weather Service (San Juan Forecast Office) to announce the Tsunami Warning for Puerto Rico, according to the Northeastern Lesser Antilles Scenario choose for

Country	Exercise Caribe Wave 21 General Statements
	Puerto Rico and the Virgin Islands. At the PRSN we monitored the activation of EMWIN, the NOAA radios, as well as the Puerto Rico EAS (as scheduled for the exercise). At PRSN we received the PTWC Dummy Message at 10:00 a.m. (14:00 GMT) through the EMWIN System. Puerto Rico Broadcaster Association will prepare a final report about the activation of the EAS System for Puerto Rico. Puerto Rico Emergency Management Bureau emits the WEA for Puerto Rico at 9:47 a.m. (13:47 GMT) to remind the public of the CARIBE WAVE 2021 communication exercise.
USA - US Virgin Islands	Exercise participation went better than expected. Mass gatherings have individuals throughout the territory nervous. Messaging needs improvement.
Venezuela	As a scientific institution, FUNVISIS carried out assessments, before, during, and after the exercise. We provided immediate advice to risk management institutions at the national, regional and municipal levels. We disseminated through our social networks and website, proper contents, and make the entire population aware of out seismological and tsunamigenic realities. We celebrate this initiative that has indeed increased national awareness of tsunamis. Even more, we open a permanent exhibition in the Science Museum, Caracas, dedicated to explaining the tsunamis and how it has historically affected Venezuela.

Table 5. General statements on Caribe Wave 21 Tsunami Exercise experience from countries that participated.

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ANNEX

LIST OF ACRONYMS

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 of UNESCO
NGDC	National Geophysical Data Center (renamed to National Centers for Environmental Information - NCEI)
NOAA	National Oceanic and Atmospheric Administration (USA)
NTWC	National Tsunami Warning
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
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
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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
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18	Global Ocean Pollution: An Overview. 1977	(out of stock)
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23	Operational Sea-Level Stations. 1983	E, F, S, R
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28	Bruun Memorial Lectures, 1982: Ocean Science for the Year 2000. 1984	E, F, S, R
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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
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
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(continued)

36	Bruun Memorial Lectures 1989: Impact of New Technology on Marine Scientific Research. 1991	Composite E, F, S
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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
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