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Working Group 1 Monitoring and Detection Systems

IOC Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions

CARIBE EWS SEA LEVEL DATA AVAILABILITY

2022 Report

Abstract

Report of coastal sea level stations and DARTs contributing to the CARIBE EWS in 2022. In December 2022, of the 184 stations in the CARIBE-EWS sea level inventory, data from 68 were available in support of tsunami warning.

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Acknowledgments

First and foremost, a special recognition to the sea level station operators and data analysts in the Caribbean and Adjacent Regions; they keep the stations running and create awareness on data issues. Our appreciation also goes out to Stuart Weinstein from the Pacific Tsunami Warning Center for generating the monthly reports and maps on sea level status and for his support and updates to Tide Tool sea level data analysis program. We also acknowledge Tjess Hernandez and Bart Vanhoorne from the IOC Sea Level Monitoring facility for maintaining this vital tool and clarification on station status and data formats. An acknowledgement also to the International Tsunami Information Center Caribbean Office (previously known as the Caribbean Tsunami Warning Program), especially Stephanie Soto, Desiree Bayouth-García and Christa von Hillebrandt-Andrade for tracking station status and preparing this report.

Summary

Real-time sea level data is one of the essential data streams of a tsunami warning system. Tsunami Warning Centers use seismic data to determine whether there is potential for a tsunami threat following an earthquake. Sea level data are used to detect and confirm the tsunami generation, help forecast its severity and to declare the threat is over. In the case of tsunamis generated by a non-seismic source, the sea level data will be the primary tool for the detection and evaluation of the threat. The main type of sea level data used to detect tsunamis are coastal sea level stations and tsunameters (DARTs).

Since 2010, at the request of the Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE EWS), the Caribbean Office of the International Tsunami Information Center has maintained an inventory of the sea level stations used for tsunami monitoring and warning in the region. It shares and posts monthly maps on the status of sea level data from the Pacific Tsunami Warning Center, periodically updates and posts the inventory of stations and their status, and produces an annual report on sea level stations and data availability.

For this report, data availability is reported from the UNESCO/IOC Sea Level Station Monitoring Facility (SLMF) for the coastal sea level stations and most recently, DART stations. The data availability at NOAA National Data Buoy Center is reported in the case of the DARTs and at the Pacific Tsunami Warning Center, as the designated Tsunami Service Provider for the CARIBE EWS, for both DART and coastal sea level stations.

In December 2022, of the 184 stations in the CARIBE-EWS sea level inventory, 68 were contributing data in near real time for tsunami warning. This includes 3 of the 8 DART stations. In contrast, in December 2021 there were a total of 177 stations and 44 contributing.

Introduction

Since 2010, the International Tsunami Information Center Caribbean Office (ITIC-CAR), previously called the Caribbean Tsunami Warning Program, CTWP, has been reviewing the status of seismic and sea level stations contributing to the CARIBE EWS. In 2021, it transitioned from preparing monthly to biannual reports on the status of coastal sea level stations and DARTs. The PTWC also prepares monthly maps on sea level data availability at their center and ITIC-CAR has posted these on caribewave.org as well as shared with CARIBE EWS WG1 and operators of sea level stations.

At its Fourteenth Session, the Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions, (ICG/CARIBE EWS-XIV) in its recommendation ICG/CARIBE-EWS-XIV.2 on Tsunami Monitoring and Detection Systems:

- Requested CTWP to continue producing up to date maps and data availability reports based on current sea level and seismic stations contributing to the CARIBE-EWS.

Furthermore, at its Fifteenth Session, which took place online 27–29 April 2021, the ICG/CARIBE EWS-XV) in its Recommendation ICG/CARIBE-EWS-XV.1 on Tsunami Monitoring and the Systems:

- Appreciated the NOAA Caribbean Tsunami Warning Programme (CTWP) for improving the automated processing and reporting on the status of seismic and sea level stations
- Urged Member States and sea level station operators contributing to CARIBE-EWS to maintain their sea-level stations to an operational standard,

- Also urged Member States and sea level station operators to regularly review and update the status of sea level stations in the web pages of the IOC's Sea Level Station Monitoring Facility and in the CTWP reports prepared on behalf of the CARIBE-EWS,
- Recommended a survey of sea-level network operator status by WG1 and ITIC-CAR with the goal of improving the up time of the sea-level network,

This report covers these recommendations.

Sea Level Stations Status Categories for 2022

In 2019, at the *Fourteenth Session of the Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions, (ICG/CARIBE EWS-XIV)* the status categories for sea level stations were updated to the following:

Contributing Real Time (Contributing RTX)	Also known as Active on the SLMF. Data from these stations have been available for the past month in real time or near real time thru FTP or GTS (GOES), are accessible to tsunami service providers and tsunami warning centers and can be accessed thru Tide Tool, IOC SLMF and other sites. For reports prepared thru 2018, once a station was contributing in real time, it always remained with this status, irrespective of its operational status. There were stations that had not been contributing data in real time for months or even years. These non-contributing stations are now classified as down, being consistent with the SLMF.
Existing	Stations that are understood to be operational through national reporting, GLOSS or other mechanisms, but whose data are not shared and are not available in real time or near real time.
Down	These stations at one point were Contributing in Real Time but for a period of a month or longer have not been sharing data. There is the expectation that the data from the station will become available in the future.
Planned	Stations that Member States or Network Operators have indicated they have funding for and are in the process of acquisition or installation.
Gap	Station locations that the CARIBE EWS has indicated are of high priority but for which no funding has been identified for their acquisition, installation, and operation.
Removed	Stations which have been removed or relocated.

Unknown	Stations for which there is no data on its current operational status.

This classification was used for the 2022 biannual sea level reports as well as this report. Figure 1 shows the status of the 176 coastal stations in the inventory at the end of 2022. Graph 1 shows the biannual number of sea level stations from December 2020 through December 2022 for which data was contributing close to real time (Contributing RTX). According to the statistics, there has been an increase in the total number of Contributing RTX stations, from 44 stations contributing at the end of 2021 to 68 in December 2022. Graph 2 shows all the status categories used for each six-month term. The biannual reports/maps were also posted to the ITIC-CAR website (caribewave.org). Appendix 1 has a table with the status of all the stations as of December 2022.

For the Contributing Real Time stations, the performance ratio statistics per station are based on the data in the UNESCO IOC Sea Level Monitoring Facility (SLMF) and the data from the Pacific Tsunami Warning Center (PTWC) was also used.

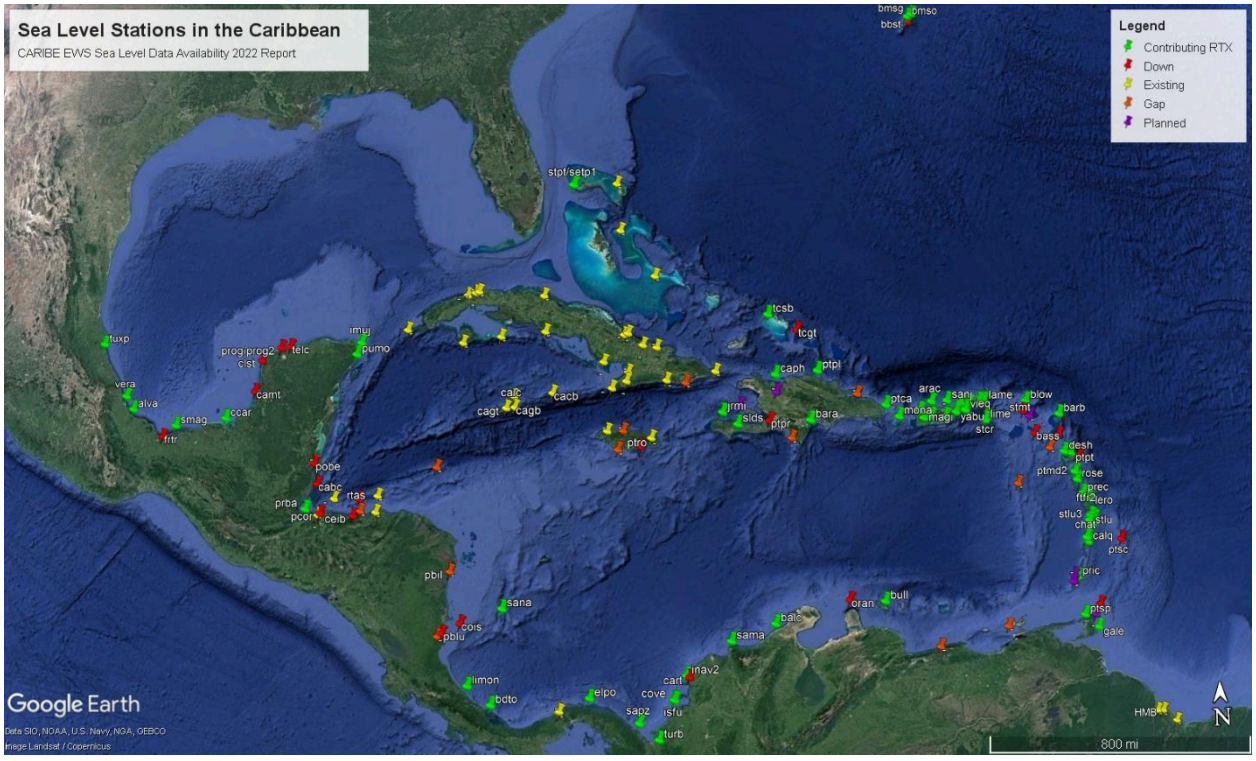
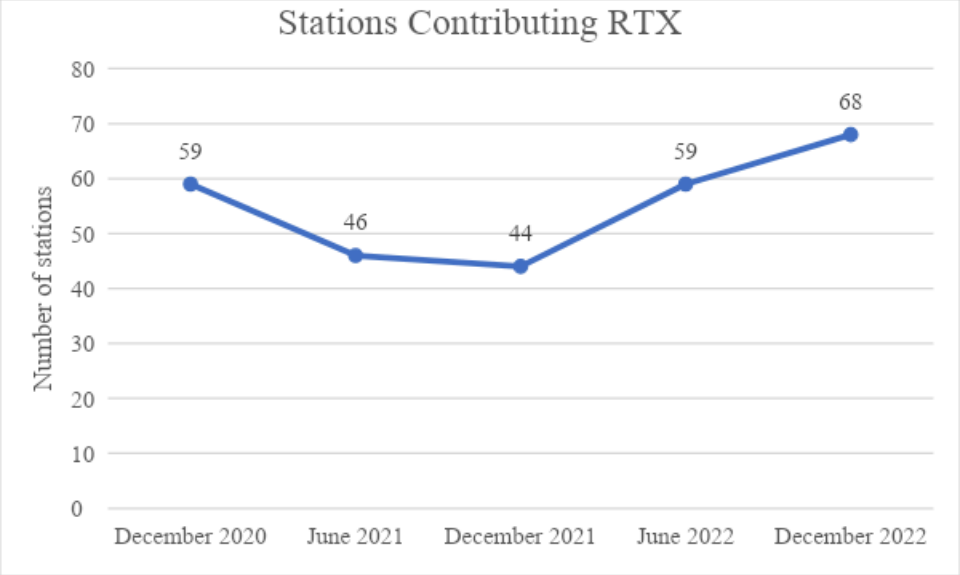
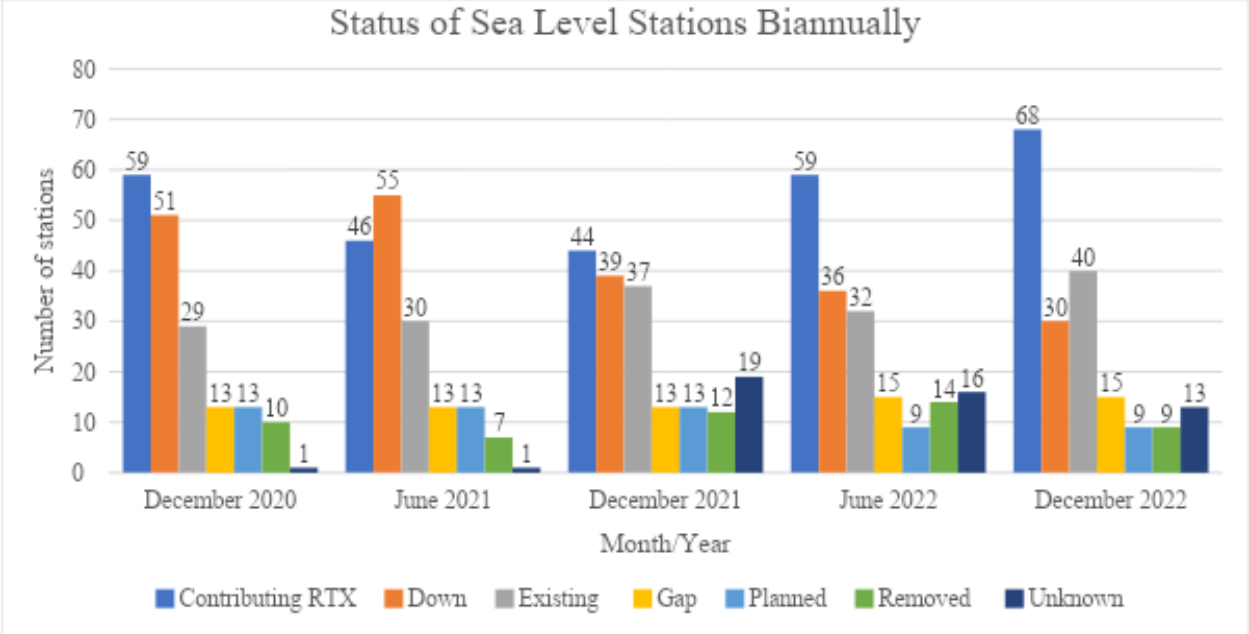


Figure 1. December 2022 Sea Level Stations Status.



Graph 1. Biannual variability of number of Contributing RTX coastal sea level stations and DARTs from December 2020 through December 2022.



Graph 2. Station Status 2020-2022

UNESCO - Intergovernmental Oceanographic Commission (IOC) Sea Level Monitoring Facility (SLMF)

The objectives of this service are:

- to provide information about the operational status of global and regional networks of real time sea level stations;
- to provide a display service for quick inspection of the raw data stream from individual stations.

This service and website (Figure 2) initially focused on operational monitoring of sea level measuring stations in Africa and was developed from collaboration between Flanders Marine Institute (VLIZ) and the ODINAFRICA project of IODE. The site has since been expanded to a global station monitoring service for real-time sea-level measuring stations that are part of IOC programs, i.e. (i) the Global Sea Level Observing System Core Network and (ii) the networks under the regional tsunami warning systems in the Indian Ocean (IOTWMS), Northeast Atlantic & Mediterranean (NEAMTWS), Pacific (PTWS) and the Caribbean (CARIBE-EWS).

In the case of the IOC SLMF, the performance ratios of the desired stations for specific time periods are accessed. A manual check is done to verify operational status and check inconsistent data. For example, if there is no sea level data, a station might appear as Contributing RTX on IOC SLMF if data on battery voltage is available. ITIC-CAR and the managers of the IOC SLMF are regularly comparing data.

A document with figures highlighting the variability of data availability per station and sensor in SLMF can also be accessed through the ITIC-CAR website. Figure 2 shows a screenshot of the map of coastal sea level stations in the IOC SLMF data base taken on January 20, 2023. As of February 2023, SLMF has been including DART stations availability in their website. More information on DARTs will be discussed in another section of this report.

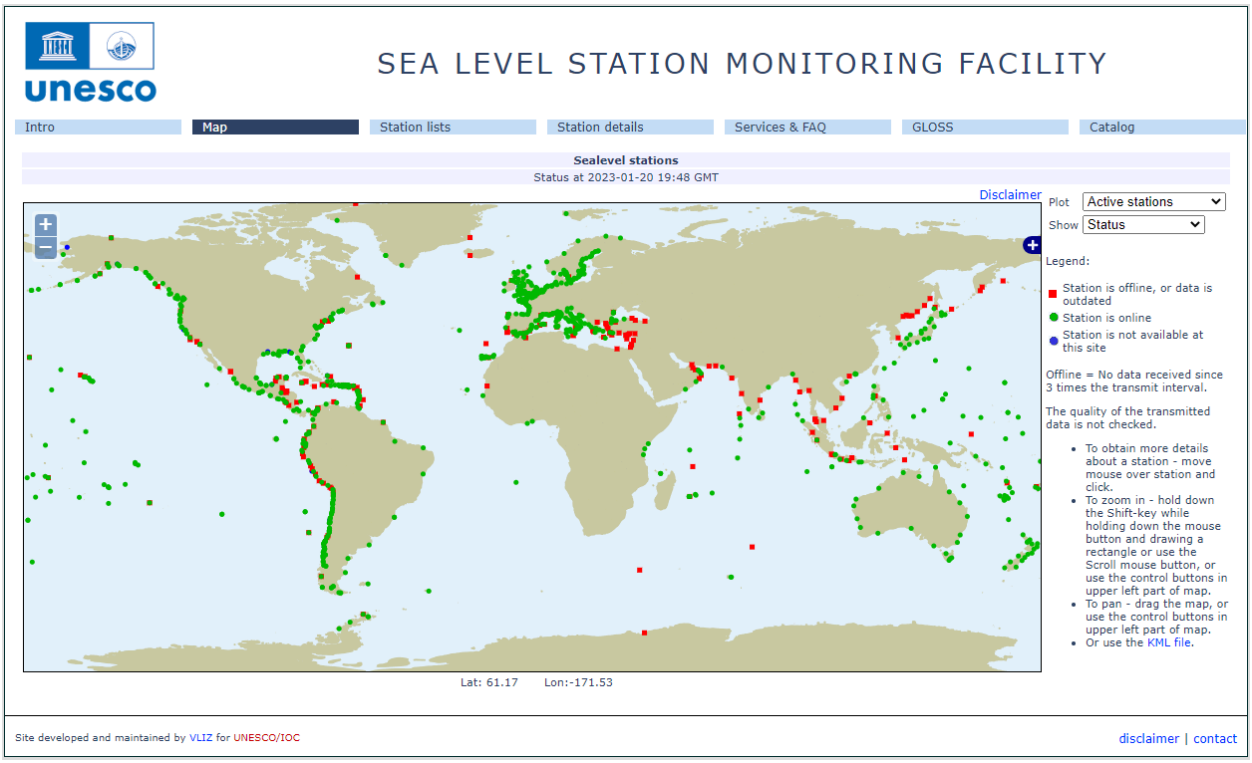


Figure 2. Screenshot of IOC Sea Level Monitoring Station Website on Map on January 20, 2023

Pacific Tsunami Warning Center (PTWC)

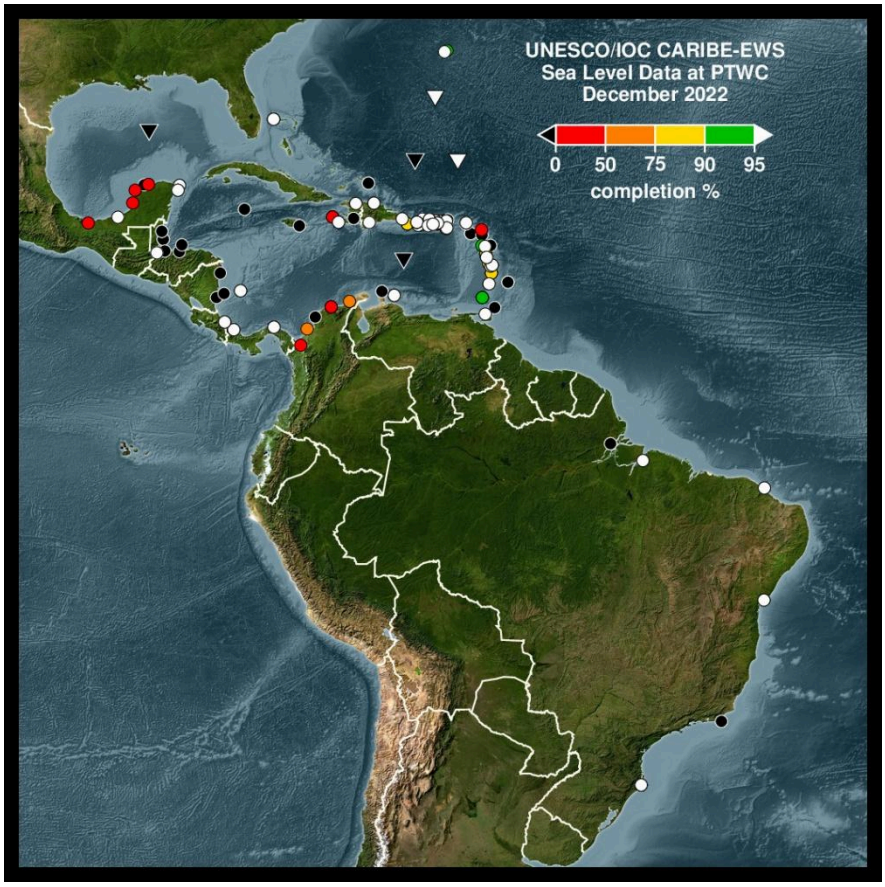
The Pacific Tsunami Warning Center (PTWC) operated by the United States National Weather Service of NOAA served from 2005-2015 as the interim Tsunami Warning Center. Since 2016 the PTWC is designated as a Tsunami Service Provider (TSP) for the Tsunami and Other Hazards Warning and Mitigation System for the Caribbean and Adjacent Seas (CARIBE-EWS), a subsidiary body of UNESCO's Intergovernmental Oceanographic Commission (IOC).

Products issued by PTWC to countries around the Caribbean in support of this mission have evolved over time as supporting data, analysis methods, computational capabilities, and communications have all improved. The products developed by the PTWC are for only advisory for the CARIBE EWS Member State. National authorities are responsible for determining the level of tsunami alert within each Member State.

On 1 March 2016, the US NOAA Pacific Tsunami Warning Center (PTWC) commenced issuance of new forecast-based Enhanced Tsunami Products for all Caribbean countries. The PTWC PTWS and CARIBE-EWS products use the same forecast methodologies and the same graphical formats to depict the tsunami threat for the basin and coastal polygons.

The PTWC depends on sea level data to confirm, forecast and determine end of threat from tsunamis in the region. In the case of non-seismic generated tsunamis, sea level data are the main mechanism used to detect and inform on tsunami threat. Over the past years the PTWC has been developing an alarm event detection system based on sea level data.

Since November 2019, the PTWC data have been incorporated into the ITIC-CAR Sea Level biannual reports to compare the data reported by the IOC SLMF with the data from PTWC. Stations reported in the PTWC are also included in the Tide Tool Sea Level Data Analysis Program. The PTWC generated map for December 2022 is shown in Figure 3. The color legend is included in the map; sea level stations are represented as circles while the DART stations are represented by triangles. These maps show the ranges of percentage availability of the *Contributing RTX* stations. *Down* stations are reported in black. *Removed*, *Planned, Gap* and *Unknown* stations are not included in the PTWC reports, nor do they appear on this map.


UNESCO/IOC CARIBE-EWS
Sea Level Data at PTWC
December 2022
0 50 75 90 95
completion %

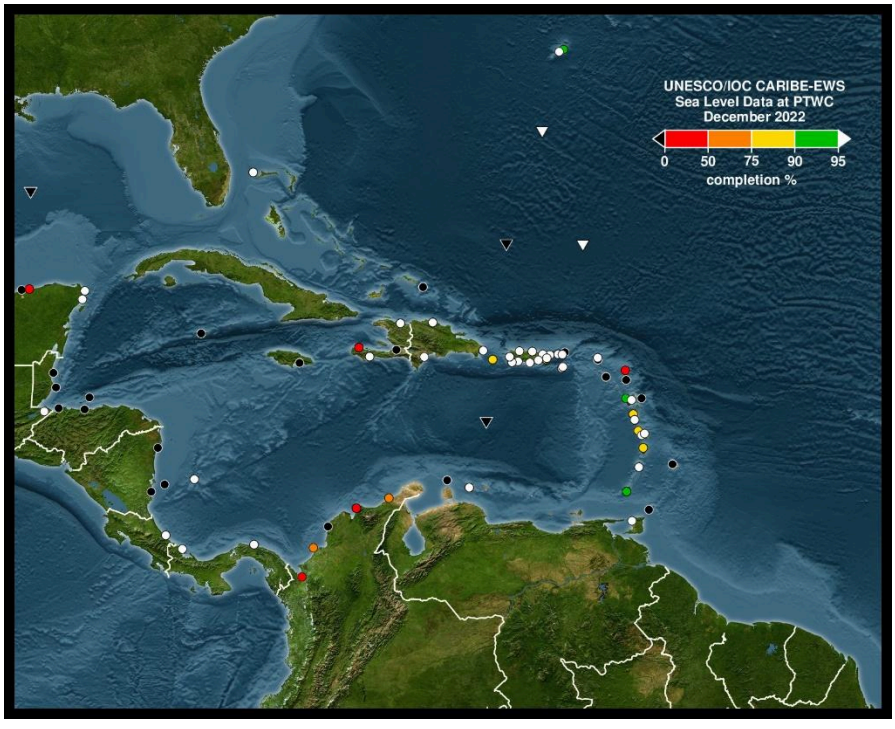

UNESCO/IOC CARIBE-EWS
Sea Level Data at PTWC
December 2022
0 50 75 90 95
completion %

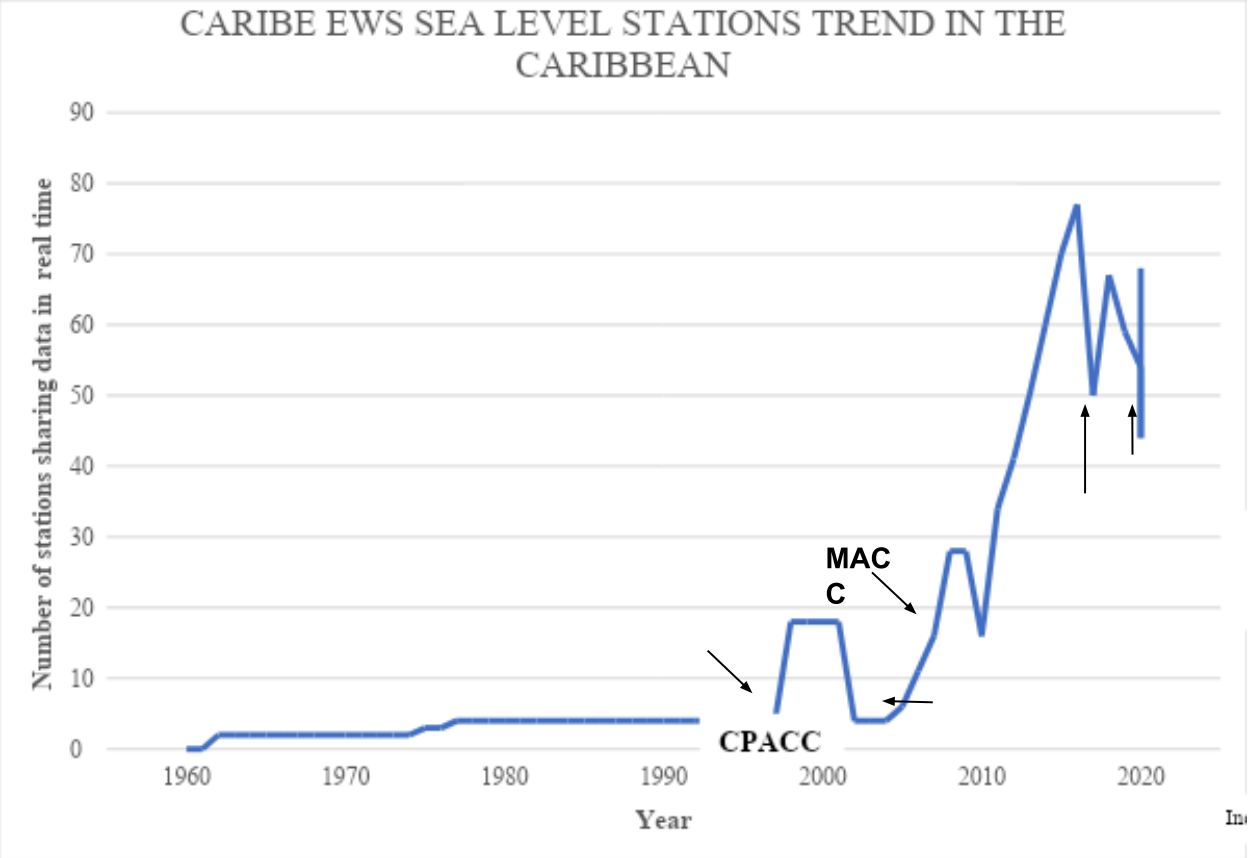
Figure 3. Regional and Expanded maps of status data from Sea Level and DART Station at PTWCs for December 2022. Circles represent coastal sea level stations and triangles DARTs. The percentage refers to the percentage of data received at the PTWC within 15 minutes of recording.

Contributing RTX Sea Level Stations

The number of Contributing RTX stations increased during the 2021 to 2022 period from 44 stations in December 2021 to 59 stations in June 2022 and the 68 in December 2022 (Table 1). Note that the usual change goes from *Contributing RTX* to *Down* and vice versa. There were a few stations removed, and others reinstalled. Also, new stations were installed in the Cayman Islands, Saint Vincent and the Grenadines, Haiti, and Puerto Rico. Other stations like from the Dominican Republic were repaired. The evolution of sea level observations since 1960 is highlighted in Graph 3. In 2022, after several years of decreasing data availability due to the impacts of Hurricanes Irma, Maria, Eta and Iota and COVID 19 the trend has reversed thanks to contributions of Member States and Donors.

Status by amount					
	Dec-20	**Jun-21**	**Dec-21**	**Jun-22**	**Dec-22**
Contributing RTX	59	46	44	59	68
Down	51	55	39	36	30
Existing	29	30	37	32	40
Gap	13	13	13	15	15
Planned	13	13	13	9	9
Removed	10	7	12	14	9
Unknown	1	1	19	16	13

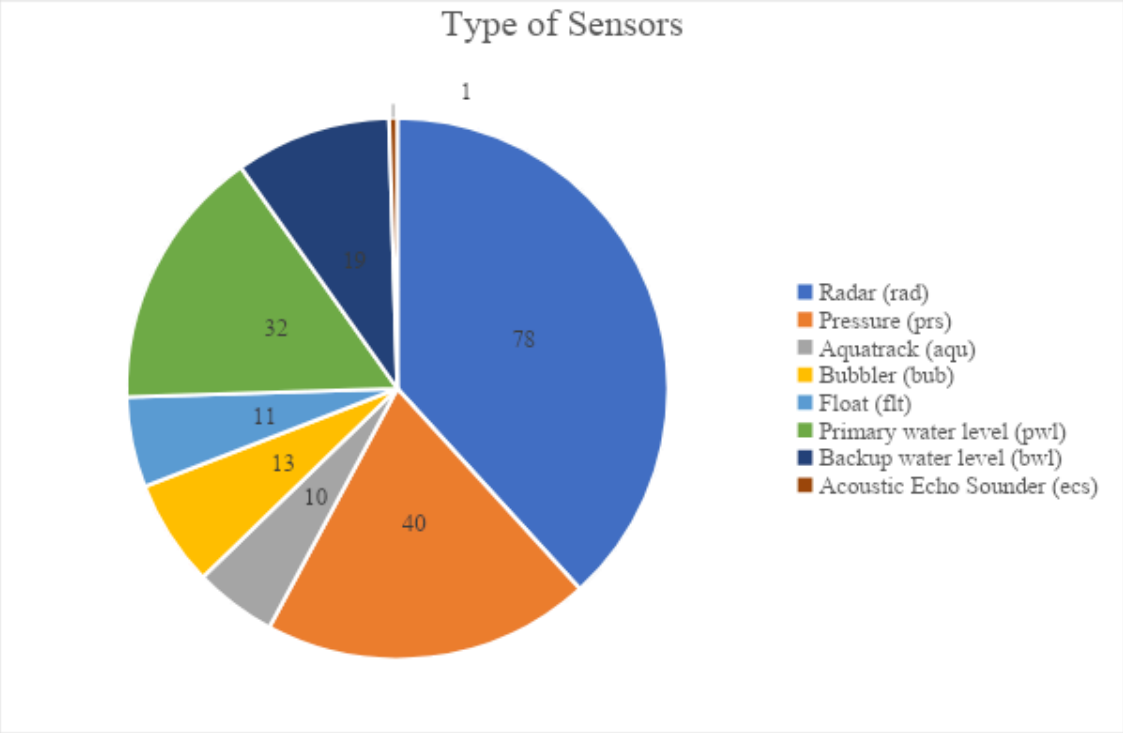
Table 1. Status of Sea Level Stations from December 2020 – December 2022.



Graph 3. Number of operational coastal sea level stations 1960 to 2022.)

Of the 184 stations being reported, 176 stations are coastal sea level stations and 8 of are DARTs. The DARTs are going to be discussed in another section of this report. For the coastal Sea Level stations, each station has one or more sensors: radars (rad, ra1, ra2), pressure (prs, pr1, pr2), float (flt) or acoustic (Aquatrack, aqu). Graph 4 shows the distribution of types of sensors. For US stations, the nomenclature of primary water level sensor (pwl) or backup water level sensor (bwl) is used depending on operational status, not on the type of sensors. In the past, the pwl were mostly Aquatrack sensors, but these have been replaced with radar sensors, while bwl sensors are bubblers or pressure sensors.

For December 2022, 68 stations were contributing RTX while 30 stations were down. The other 86 stations are existing (data not available), removed, planned, unknown or represent gaps in monitoring.



Graph 4. Types of sensors for 2022.

DART

To facilitate early detection of tsunamis and to acquire data critical to real-time forecasts, NOAA operates Deep-ocean Assessment and Reporting of Tsunami (DART®) stations at sites in regions with a history of generating destructive tsunamis. NOAA completed the original 6-buoy operational array (map of original six stations) in 2001 and expanded to a full network of 39 stations in March 2008. See DART® development for more info. Since 2008 there have been changes of locations and upgraded technology.

The National Data Buoy Center (NDBC) currently is responsible for the operation of the DARTs. However, the Pacific Tsunami Warning Centre and the IOC Sea Level Monitoring Facility also report DART stations availability using NOAA web services.

The DARTs in the Caribbean and Atlantic and included in the report are: Southeast Block Canyon (DART 44402), Sable Island Bank (DART 44403), Southwest Bermuda (DART 41425), South of Puerto Rico (DART 42407), Gulf of Mexico (DART 42409), Dart Wave Glider Station, West Florida Area (DART 42429), North of St. Thomas (DART 41421) and North of Santo Domingo (DART 41420). At the end of 2022 the only stations reporting data online were the DARTs in the Southeast Block Canyon, Southwest Bermuda, and North of St. Thomas (Figures 4 and 5). Graph 5 illustrates the variability of availability of DART data between December 2020 and 2022.

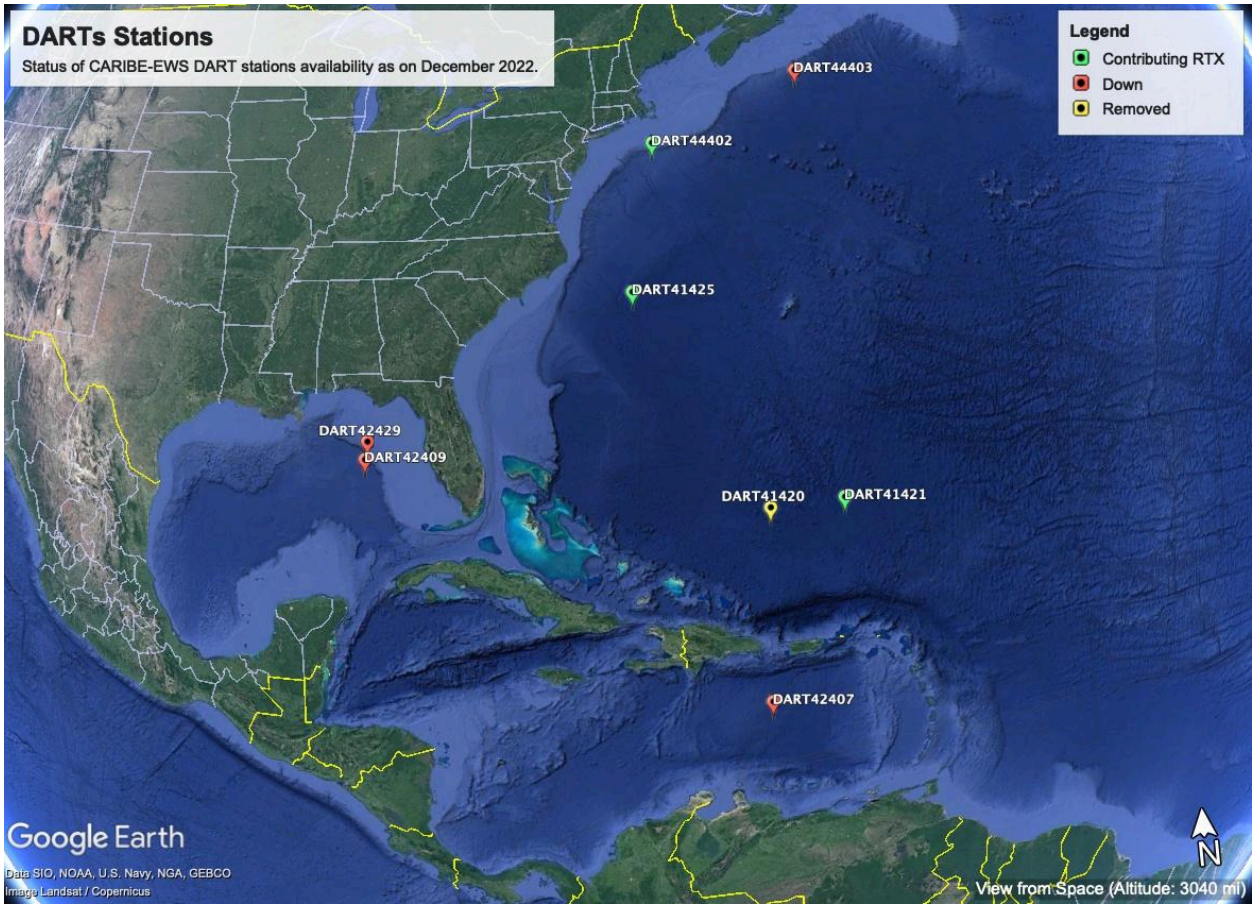


Figure 4. Map of DART stations for December 2022.

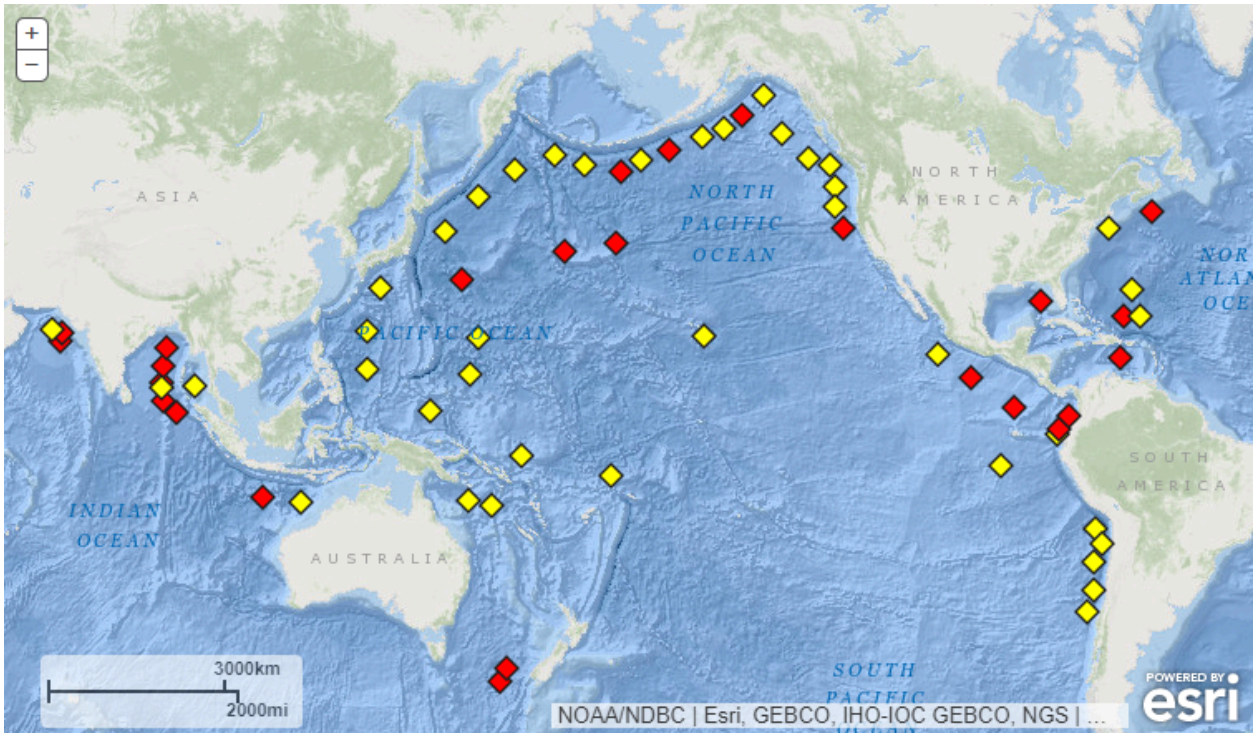
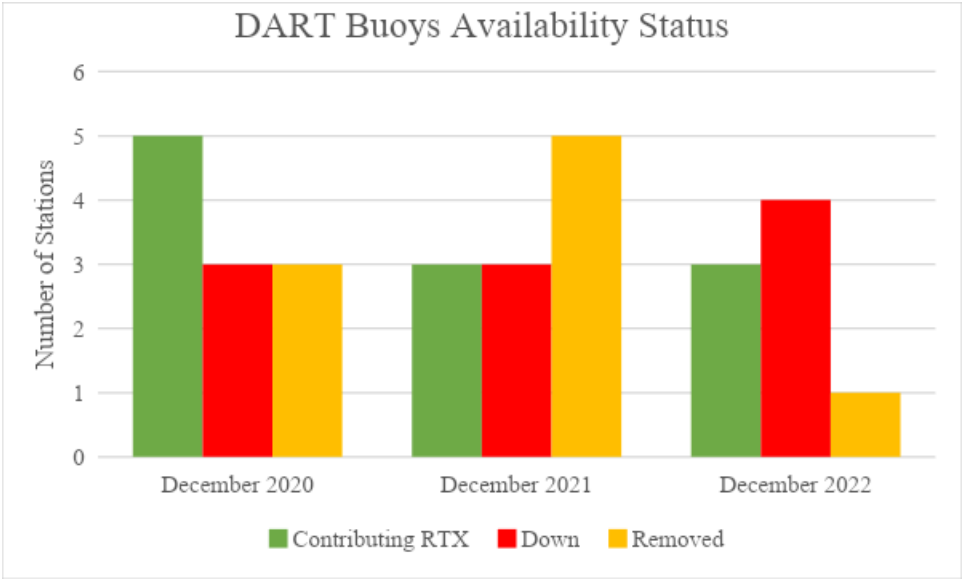


Figure 5. Originally developed by NOAA, as part of the U.S. National Tsunami Hazard Mitigation Program (NTHMP), the DART® Project was an effort to maintain and improve the capability for the early detection and real-time reporting of tsunamis in the open ocean.[1] January 20, 2023. Stations in yellow are operational and in red non operational.



Graph 5. DART Buoys availability status December 2020 – December 2022.

[1] https://www.ndbc.noaa.gov/dart/dart.shtml

Appendix List

- Appendix A: Sea Level Station List and Status 2022

Appendix A: Sea Level Stations December 2022

Station name	**Country**	**Status**[2]
Blowing Point	Anguilla	Contributing RTX
Barbuda	Antigua and Barbuda	Contributing RTX
Parham (Camp Blizard), Antigua	Antigua and Barbuda	Down
Oranjestad	Aruba	Down
Settlement Point	Bahamas	Contributing RTX
Lee Stocking Island, Exuma	Bahamas	Existing
Matthew Town, Inagua	Bahamas	Existing
Nassau Harbour, New Providence	Bahamas	Existing
Treasure Cay, Abaco	Bahamas	Existing
Bridgetown Port	Barbados	Unknown
Port St. Charles	Barbados	Down
Pelican Fort	Barbados	Removed
Conset Bay	Barbados	Removed
Speightstown	Barbados	Removed
Carrie Bow Cay	Belize	Down
Belize City	Belize	Planned
Belize	Belize	Existing
Port of Belize	Belize	Down

[2] For Contributing Stations are being received at PTWC, integrated into Tide Tool and available on the IOC Sea Level Monitoring Facility. DART stations are also available through the NOAA National Data Buoy Center

St. Georges Cruice Pier	Bermuda	Contributing RTX
St. Georges Island / Esso Pier	Bermuda	Unknown
Bermuda Biological Station	Bermuda	Down
Bermuda Somerset	Bermuda	Contributing RTX
Road Town Harbor, Tortola	British Virgin Islands	Down
Cayman Brac	Cayman Islands	Existing
George Town	Cayman Islands	Existing
Gun Bay	Cayman Islands	Existing
Little Cayman	Cayman Islands	Existing
Ballenas	Colombia	Contributing RTX
Cartagena	Colombia	Down
San Andres	Colombia	Contributing RTX
Santa Marta	Colombia	Contributing RTX
Capurganá	Colombia	Removed
Sapzurro	Colombia	Contributing RTX
Turbo	Colombia	Contributing RTX
Islas del Rosario	Colombia	Removed
Isla Naval	Colombia	Contributing RTX
Isla Fuerte	Colombia	Contributing RTX
Coveñas	Colombia	Contributing RTX
Puerto Estrella	Colombia	Unknown

Limón	Costa Rica	Contributing RTX
Cabo Cruz	Cuba	Existing
Cabo San Antonio - Morros de Piedra	Cuba	Existing
Gibara	Cuba	Existing
Isabela de Sagua	Cuba	Existing
Manzanillo	Cuba	Existing
Guantanamo	Cuba	Gap
Casilda	Cuba	Existing
Maisí	Cuba	Existing
Mariel Boca	Cuba	Existing
Bahia de la Habana	Cuba	Existing
Nuevitas Punta de Practicos	Cuba	Existing
Puerto Padre	Cuba	Existing
Nuevitas Bufaderos	Cuba	Existing
Siboney	Cuba	Existing
Santiago de Cuba	Cuba	Existing
Santa Cruz del Sur	Cuba	Existing
Carapachibey	Cuba	Existing
Cayo Loco	Cuba	Existing
Cayo Largo	Cuba	Existing
La Coloma	Cuba	Existing
Bullen Bay	Curacao	Contributing RTX
Portsmouth	Dominica	Planned
Marigot	Dominica	Unknown
Roseau	Dominica	Contributing RTX

Portsmouth	Dominica	Contributing RTX
Barahona	Dominican Republic	Contributing RTX
Puerto Caucedo/San Andres/Santo Domingo	Dominican Republic	Unknown
Puerto Plata	Dominican Republic	Contributing RTX
Punta Cana	Dominican Republic	Contributing RTX
Bahía de Luperón	Dominican Republic	Gap
Bahía de Samaná	Dominican Republic	Gap
Bayahibe	Dominican Republic	Gap
Pedernales	Dominican Republic	Gap
Puerto de Santo Domingo	Dominican Republic	Removed
Ile Royale	French Guiana	Contributing RTX
Prickly Bay	Grenada	Contributing RTX
Sauteurs	Grenada	Planned
The Sisters Island	Grenada	Planned
Pointe à Pitre	Guadeloupe	Contributing RTX
Deshaies Harbour	Guadeloupe	Contributing RTX
La Désirade Island, Grande Anse Marina Harbour	Guadeloupe	Down
Puerto Barrios	Guatemala	Contributing RTX
Harbour Master Boathouse	Guyana	Existing
Market Place Georgetown	Guyana	Existing
Rosignol	Guyana	Existing

Parika	Guyana	Existing
Cap Haitien	Haiti	Contributing RTX
Jacmel	Haiti	Unknown
Port au Prince	Haiti	Down
Gonaives	Haiti	Planned
Port de Paix	Haiti	Planned
Jeremie	Haiti	Contributing RTX
St. Louis du Sud	Haiti	Contributing RTX
Guanaja Island	Honduras	Existing
Omoa	Honduras	Existing
Puerto Cortes	Honduras	Down
Puerto De Castilla, Trujillo	Honduras	Existing
Roatan N	Honduras	Existing
Punta Gorda Harbor, Roatan S	Honduras	Down
Tela Harbor	Honduras	Unknown
Utila Island	Honduras	Unknown
Cabotaje Harbor, La Ceiba	Honduras	Down
Cochino Pequeño	Honduras	Gap
Swan Island	Honduras	Gap
Port Royal	Jamaica	Down
Montego Bay	Jamaica	Existing
Port Antonio	Jamaica	Existing
Discovery Bay, Jamaica	Jamaica	Gap
Alligator Pond	Jamaica	Gap

Fort de France Harbour	Martinique	Contributing RTX
Le Precheur Harbour	Martinique	Contributing RTX
Le Robert	Martinique	Contributing RTX
Alvarado	Mexico	Contributing RTX
Celestun	Mexico	Down
Ciudad del Carmen	Mexico	Contributing RTX
Lerma Campeche	Mexico	Down
Frontera	Mexico	Down
Isla Mujeres	Mexico	Contributing RTX
Progreso	Mexico	Down
Puerto Morelos, Q. R.	Mexico	Contributing RTX
Sanchez Magallanes	Mexico	Contributing RTX
Sisal	Mexico	Unknown
Tuxpan	Mexico	Contributing RTX
Telchac	Mexico	Down
Veracruz	Mexico	Contributing RTX
Montserrat	Montserrat	Gap
Corn Island	Nicaragua	Down
Blue Fields	Nicaragua	Gap
Puerto Bilwi	Nicaragua	Down
Puerto Cabezas	Nicaragua	Gap

Puerto El Bluff	Nicaragua	Down
El Porvenir	Panama	Contributing RTX
Bocas del Toro	Panama	Contributing RTX
Galeta Point	Panama	Existing
Limon Bay (replaced Coco Solo)	Panama	Existing
Aguadilla	Puerto Rico	Unknown
Arecibo	Puerto Rico	Contributing RTX
Culebra Island	Puerto Rico	Contributing RTX
Fajardo	Puerto Rico	Contributing RTX
Guayanilla	Puerto Rico	Contributing RTX
Isabel II, Vieques	Puerto Rico	Contributing RTX
La Esperanza, Vieques	Puerto Rico	Contributing RTX
Magueyes Island	Puerto Rico	Contributing RTX
Mayagüez	Puerto Rico	Contributing RTX
Mona Island	Puerto Rico	Contributing RTX
Salinas	Puerto Rico	Contributing RTX
San Juan	Puerto Rico	Contributing RTX
Yabucoa	Puerto Rico	Contributing RTX
Peñuelas	Puerto Rico	Removed

Caja de Muertos	Puerto Rico	Removed
Baseterre (Coast Guard Base)	St. Kitts & Nevis	Down
Dennery Harbour	St. Lucia	Contributing RTX
Soufriere	St. Lucia	Contributing RTX
Vieux Fort Bay	St. Lucia	Contributing RTX
Ganter's Bay	St. Lucia	Contributing RTX
Calliaqua (Coast Guard Base)	St. Vincent & the Grenadines	Contributing RTX
Chateau Bel-Air	St. Vincent & the Grenadines	Contributing RTX
Gustavia	St. Barthelemy	Planned
Saint Martin Island	St. Martin	Down
Cedros Bay	Trinidad and Tobago	Unknown
Charlotteville	Trinidad and Tobago	Unknown
Point Fortin	Trinidad and Tobago	Unknown
Port Of Spain	Trinidad and Tobago	Contributing RTX
Scarborough	Trinidad and Tobago	Down
Toco Trinidad	Trinidad and Tobago	Planned
Point Galeota	Trinidad and Tobago	Contributing RTX
Point a Pierre	Trinidad and Tobago	Planned
Grand Turk	Turks and Caicos	Down
Sapodilla Bay, Providenciales	Turks and Caicos	Contributing RTX
Charlotte Amalie, St. Thomas	USVI	Contributing RTX

Christiansted Harbor, St. Croix	USVI	Contributing RTX
Lameshur Bay, St. John	USVI	Contributing RTX
Lime Tree Bay, St. Croix	USVI	Contributing RTX
Aves Island	Venezuela	Gap
Punta Arenas, Margarita Island	Venezuela	Gap
La Guaira	Venezuela	Gap