

Intergovernmental Oceanographic Commission
Reports of Governing and Major Subsidiary Bodies



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

Eleventh Session

Cartagena de Indias, Colombia
5–7 April 2016

Annex IV

TECHNICAL, LOGISTICAL AND ADMINISTRATIVE REQUIREMENTS OF A REGIONAL
TSUNAMI SERVICE PROVIDER FOR THE CARIBE-EWS

UNESCO

¹ This report contains a summary in English, French, Spanish and Russian

ANNEX IV

**TECHNICAL, LOGISTICAL AND ADMINISTRATIVE
REQUIREMENTS OF A REGIONAL TSUNAMI SERVICE
PROVIDER FOR THE CARIBE-EWS**

EXECUTIVE SUMMARY

One of the main action items of the UNESCO-IOC ICG/CARIBE-EWS is the establishment of a fully functional Tsunami Warning System for the Caribbean and Adjacent Regions (CTWS). At its tenth session in Philipsburg, Sint Maarten, the ICG adopted a Tsunami Service Model (Figure 1). Following this model, the Regional Tsunami Service Provider (RTSP) will replace the interim service being provided by the Pacific Tsunami Warning Center to the Region. At ICG-X, the Tsunami Service Model Task Team was instructed to prepare documents describing the various elements of the Tsunami Service Model for the Caribbean and Adjacent Regions, taking into account the discussions at ICG-X, the relevant recommendations from TOWS-WG and considering the work and documentation provided for other Tsunami Warning Systems on defining these operational requirements. This document describes the RTSP, one of the main components of the Tsunami Service Model.

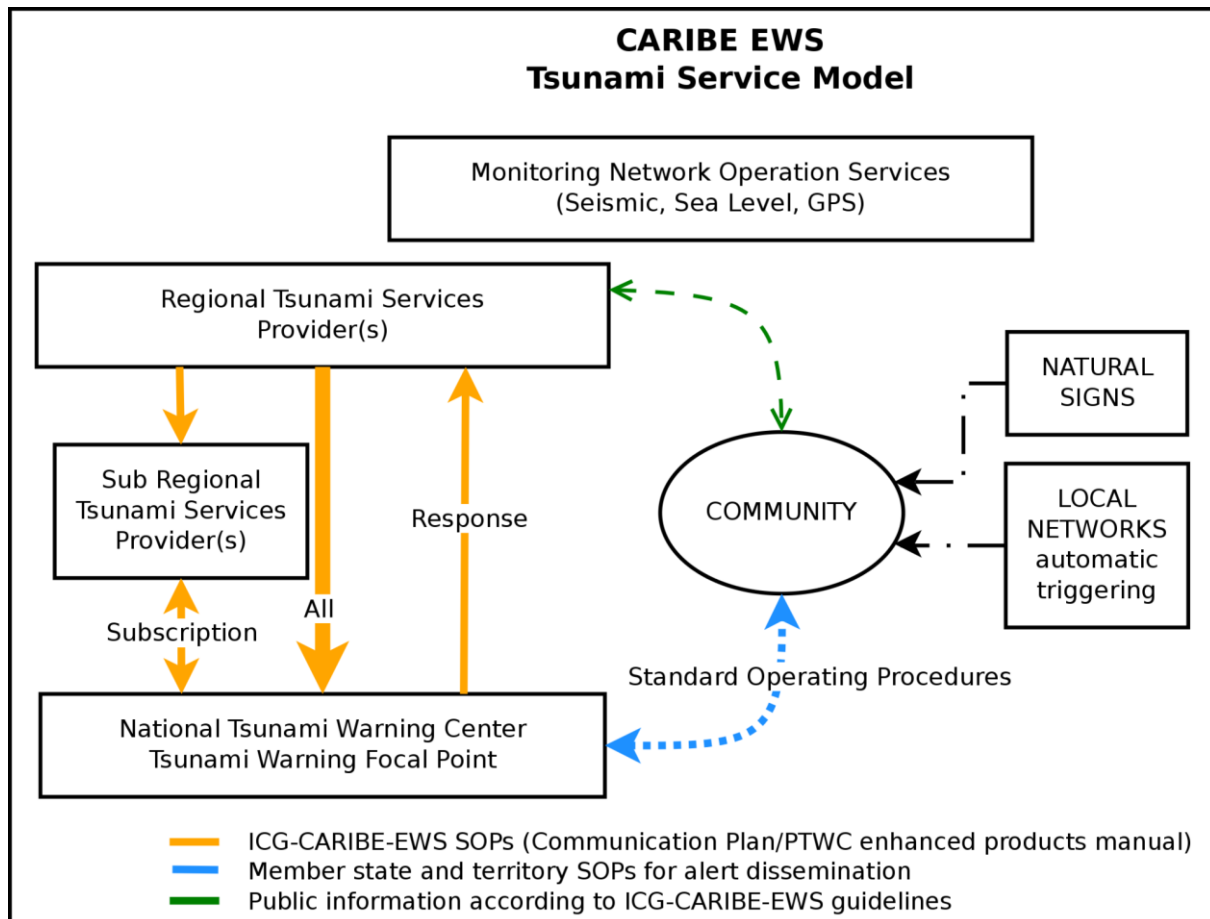


Figure 1. ICG CARIBE-EWS Tsunami Service Model (ICG-X 2015).

INTRODUCTION

A **Tsunami** is a series of waves generated by a displacement of the water column by an undersea earthquake, volcanic eruption, landslide or meteor impact. Offshore earthquakes are by far the most common cause of tsunamis. In deep waters they can travel as fast as

500 miles per hour, equivalent to the speed of a commercial jet. When the tsunami approaches the coast, its speed decreases drastically as well as the distance between the waves, causing its height to increase up to dozens of feet with the potential of causing extensive destruction and loss of lives.

History and ongoing research confirms the very high risk of the Caribbean coasts to tsunamis (Figure 2). The most significant source is a local earthquake, although tsunamis from volcanic eruptions and regional and distant earthquakes and submarine landslides also threaten the low lying coastal areas. With growing populations, increasing tourism, and concentration of infrastructure along vulnerable coastlines, events of similar proportions to those which have occurred historically carry a very high level of risk and must be anticipated and addressed (von Hillebrandt, 2013).

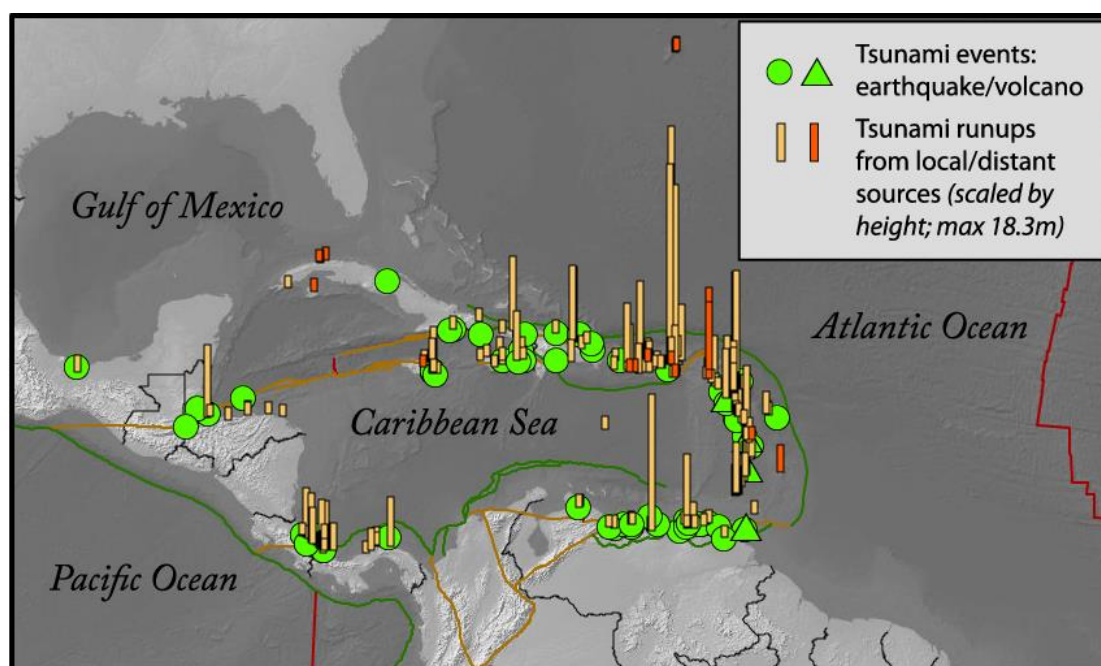


Figure 2. Maps of historical tsunamis in the Caribbean basin and their relative source (von Hillebrandt-Andrade, Christa, 2013. *Minimizing Caribbean Tsunami Risk, Science, Vol. 341*pp. 966-968).

For tsunami prone areas, the IOC tsunami experience has shown a Tsunami Service Provider (TSP) and accompanying Tsunami Information Centres (TIC) working closely with the national authorities to be essential and critical organizational components for the successful operation of a Tsunami Warning System (TWS).

Since 2005, the PTWC has agreed to provide an interim tsunami advisory information service to the Caribbean and adjacent regions. Since June 2007, the US National Tsunami Warning Center (US-NTWC, previously known as the West Coast and Alaska Tsunami Warning Center) has been providing interim tsunami warning service for Puerto Rico and the US and British Virgin Islands. To cover the needs of the Caribbean, the ICG/CARIBE-EWS II and III had recommended that a Caribbean Tsunami Warning Centre must be established by 2010. This recommendation has been superseded by a Regional Tsunami Service Provider (RTSP) within the context of the Tsunami Service Model recommended by ICG -X.

MISSION

The RTSP will provide timely and effective tsunami threat assessments (and based on those assessments will disseminate regional tsunami services products to) for all ICG/CARIBE-EWS Member States.

DUTIES

The RTSP will monitor the Caribbean and adjacent regions for tsunamis threat and inform its customers and partners of potentially tsunamigenic events and the associated tsunami threat. The authoritative tsunami warning agency (Tsunami Warning Focal Point (TWFP) and/or National Tsunami Warning Center (NTWC)) for each Member State is designated its government and has the fundamental responsibility for public safety in a tsunami emergency. The authority for issuing tsunami warning instructions to the public resides with this agency and not with RTSP.

In order to fulfill its mission, the RTSP responsibilities will encompass the following:

1. Acquire in real time the seismic data from as many seismic stations as possible and necessary to meet the detection thresholds. These data are to be provided by the global, regional, sub regional, national and local seismic networks.
2. Monitor the seismic data streams to locate and analyze earthquakes to determine the tsunami threat for the area of coverage (AOC) of the ICG/CARIBE-EWS.
3. Establish cooperation with other TWC, TWS's and TSP's, (e.g. PTWC/S, NEAMTWS) particularly for the monitoring of teleseismic tsunamis that could affect the ICG/CARIBE-EWS's AOC.
4. Monitor coastal and ocean (DART buoys) sea level data around the Caribbean and Adjacent Areas and integrate into tsunami evaluation procedures and products.
5. Compute the estimated arrival times (ETA's) and amplitudes of the tsunamis for coastal point of interests designated by ICG/CARIBE-EWS.
6. Disseminate Tsunami products (information statements, tsunami threat levels), including to all TWFP and/or NTWC designated by the Member States, according to the ICG/CARIBE-EWS recommendations.
7. Monitor the observational data that is received to ascertain that it meets the specifications established by the ICG/CARIBE-EWS.
8. Evaluate and develop new technologies (software, hardware, algorithm ...) to improve tsunami monitoring and tsunami services. Cooperate with international research groups on tsunami science.
9. Coordinate data and products with NTWCs in the region and other tsunami service providers.
10. Coordinate with international data centres to maintain historical tsunami databases for the Caribbean.
11. Develop, maintain and update the necessary documentation, including Tsunami Products Users Guide.
12. Develop IT processes and systems, including security measures, necessary to carry out responsibilities 24/7.
13. Maintain communication links (including scheduled and unscheduled tests) with Tsunami Warning Focal Points and National Tsunami Warning Centres.

14. Prepare summary reports (including timelines) on tsunami communication tests and whenever a tsunami related event occurs.
15. Prepare annual report on RTSP activities for CARIBE-EWS, including key performance indicators (Table 4).

OPERATIONAL REQUIREMENTS

The key operational components of the Regional Tsunami Service Provider (RTSP) are to provide real-time monitoring, information on potential tsunami events, timely decision making and dissemination of tsunami products, as agreed by the ICG/CARIBE-EWS.

The operational requirements can be divided into technical and logistical requirements.

Technical Requirements

Earth Data Observations

Observational data (including seismic and sea level) from international, regional, national and local networks

The RTSP must have access to as many global, regional, sub-regional, national, local and their own seismic and sea level stations (see table 1 and table 2 for, respectively, seismic and sea-level stations requirements) in order to detect earthquakes and confirm and forecast potential tsunamis. Mechanisms and procedures need to be developed to also detect and inform the Member States on tsunamis caused by non-seismic sources, such as landslides and volcanic eruptions.

The rapid detection and characterization of tsunami-generating earthquakes provides the first indication of a potential tsunami in an end-to-end tsunami warning system. All earthquakes will be processed and the result disseminated according to ICG/CARIBE-EWS thresholds. Standardized seismic location, magnitude and depth parameters should be disseminated within 5 minutes.

Initial seismic-based tsunami threat level information is subsequently refined by the detection of tsunami-generated changes in sea level, measured by coastal tide gages and buoys.

Data and Information Requirements

Telecommunications methods and connections

Several telecommunications connections are required to collect real-time data needed to detect earthquakes and tsunamis and to collaborate with other centres and disseminate critical products messages to its customers and clients. Some data, especially seismic and sea level data from international networks, is available in real time through the internet and satellite downlinks.

To obtain seismic data in a timely fashion RTSP will use Internet, dedicated circuits and/or regional VSAT methods. For sea level data, the RTSP will need to use international communication methods like GOES or Global Telecommunications System (GTS) of the World Meteorological Organization's (WMO), and Internet. The RTSP should also acquire, in the most effective and efficient way, real-time earthquake and tsunami information released by other tsunami service providers and international, regional and local earthquake observatories, such as the U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC), the PTWC, and NTWCs. Information could be acquired through faxes, Internet web sites, the

GTS, and other alternate public and non-public information sources. In all cases, the communications programmes will be continually maintained and upgraded by an Information Technology Officer (ITO) on the centre staff. They must be continually tested to make sure they will be performing as needed during actual events. When tests indicate a failure, the problem should be resolved as quickly as possible as the next event can occur at any time.

Tsunami threat level System Decision Support

Development, adaptation and/or upgrade of Tsunami forecast models

The forecast of whether a tsunami has or has not been generated from a seismic event, and the refinement of the forecast by additional observational data (including seismic and sea level) processing and analysis requires the incorporation of observational data from the communications channels into an integration and analysis subsystem. A decision-making subsystem that is composed of useful aids to the operational watch stander is needed to assist making quick decisions on the issuance of tsunami products. This may be an automated system or one that is an interactive human-machine mix.

System to assess the potential impact of the tsunami

This is contemplated as a tsunami forecast subsystem that should have an appropriate historical database and a forecast system to estimate arrival times and wave heights at coastal locations.

Equipment and Maintenance Requirements

At a minimum, the RTSP maintenance program will consist of computer hardware and software maintenance. This includes local area network and communications hardware and software maintenance and upgrades. Technicians may also be called upon to maintain physical plant systems such as backup generators, telephone systems, etc.

Logistical Requirements

Tsunami Service Products

In order to take advantage of existing international resources and the experiences of the Pacific and other Tsunami Service Providers and to maintain already established standard parameters and formats, the RTSP will issue tsunami products according to the ICG/CARIBE-EWS Users Guide (previously known as communications plan)³:

Tsunami Threat: A Tsunami Threat will be issued by the RTSP when there is a threat for a potential tsunami that may produce strong currents or waves dangerous to those in or near the water. Coastal regions historically prone to damage due to strong currents induced by tsunamis are at the greatest risk. The threat may continue for several hours after the arrival of the initial wave, and different threat levels (wave heights) can be assigned to different areas.

Information Statement: An Information Statement will be issued to inform emergency management officials and the public that an earthquake has occurred. In most cases, Information Statements are issued to indicate there is no threat of a destructive tsunami affecting the RTSP's AOC and to prevent unnecessary evacuations, as the earthquake may have been felt in coastal areas. An Information Statement may, in appropriate situations, caution about the possibility of destructive local tsunamis. Information Statements may be reissued with additional information, though normally these messages are not updated. However, a Tsunami Threat message may be issued for the area, if necessary, after analysis and/or updated information becomes available.

³ Adapted from the Tsunami Warning Center Reference Guide, USAID and WCATWC

Product Content: Tsunami bulletins or statements will be issued by the RTSP, when an earthquake with the magnitude 6.0 or greater occurs or when an event cause concern about tsunami potential. The products should contain:

Earthquake Information:

Origin time (UTC), Coordinates (latitude and longitude) of the epicenter, Location (name of geographical area), Magnitude (M) and Depth.

Tsunami Information:

- 1) Evaluation of tsunamigenic potential based on the empirical relationship between magnitude of earthquake and generation/non-generation of tsunami in the CARIBE-EWS AOC basin.
- 2) Estimated tsunami travel times to reach the respective coasts in the CARIBE-EWS AOC (only when a tsunami threat is issued). This is best handled by specifying forecast points that are well known to emergency managers and the population.
- 3) Tsunami impact information whenever available.

For non-seismic potential tsunami events, a situation assessment and tsunami threat evaluation will be provided, based on available information.

All these products have to be subject to the World Meteorological Organization, IOC, TOWS or any other ICG-approved standards. The geographic region has been defined by the ICG.

Dissemination and Notification

Since a comprehensive information dissemination program is critical to an effective tsunami warning system the RTSP will ensure that all the officially designated CARIBE EWS Tsunami Warning Focal Points and National Tsunami Warning Centers are sent at no cost the products thru the established communications methods. The products will also be sent to the SRTSP's. The entire dissemination system, from the RTSP to the NTWC/TWFP's and SRTSP's, should be tested on a routine basis with scheduled and unscheduled tests. Dissemination processes should take advantage of all technologies available to the RTSP and be automated as much as possible to decrease the time required to issue products and improve efficiency in providing threat levels. There should be redundant communications paths to ensure receipt of critical data and complete dissemination of all tsunami products. GTS should be used for the dissemination of the text products, as well as any other alternatives for disseminating information, including graphical products, to the established RTSP bulletin recipients, including, but not limited to:

- Email
- Telephonic faxes
- Web pages, web-based technology (public products only)
- TCP/IP Protocols
- Satellite-based communication systems

The RTSP will monitor the Caribbean and Atlantic Basins for seismic events and tsunamis and inform and advise the institutions designated by the Member States. However, the authoritative tsunami warning agency (e.g. Tsunami Warning Focal Point, National Tsunami Warning Centre) for each country, territory or administrative area is designated by its central government or administrative head and has the fundamental responsibility for public safety in a tsunami emergency. The authority for issuing tsunami warning and instructions to the public resides with this agency and not with RTSP.

The RTSP should collect from each NTWC and/or TWFP an acknowledgement and the response taken locally to the Tsunami Threat bulletins.

In addition to the official products issued to the TWFP's, NTWC's and SRTSP's, the RTSP will also establish mechanisms to disseminate public products according to the recommendations of the CARIBE-EWS using, but not limited to:

- Web sites;
- Social Media.

Community Connections

Local preparedness and commitment is the key for the CARIBE-EWS success, including the RTSP, because ultimately, warning systems will be judged on their ability to reach people in the at risk areas and to lead them safely inland or to higher ground before the first tsunami waves hit. The goal and focus of the RTSP outreach should be to ensure the understanding of their operational responsibilities among its stakeholders. During actual tsunami events, the RTSP should have a person designated to coordinate media response. The RTSP should also support training and guidance to NTWC/TWFP's representatives, respond to media requests, organize news conferences, coordinate briefings and tours at the RTSP, develop informational materials, assist with briefings of government officials. All these activities need to be coordinated with the CTIC and CTWP.

Administrative Requirements

The administrative requirements refer to the organizational capacity requirements of the RTSP. The RTSP will require the resources necessary to conduct 24/7 operations as well as maintain all the data streams, computers, computer programs and communications needed to fulfill its mission. It has to be sustainable with the political will and adequate funding to ensure sustainability well into the future. This must be clearly stated by the hosting Member State.

It should be physically and technologically accessible to the scientific and hazard management community of the ICG/CARIBE-EWS. No political restrictions should apply. This must be clearly stated by the hosting Member State.

The RTSP should maintain up-to-date documentation including a user's guide, standard operating procedures and agreements with partners. The list of TWFP, NTWC, and SRTSP provided through UNESCO/IOC should be reviewed frequently to secure its performance under emergency conditions. Finally, the goal for the RTSP should be to maintain or exceed the capability and interoperability requirements as defined by the IOC and the ICG/CARIBE-EWS.

Staffing Requirements

In addition to staffing around-the-clock operational shifts, additional resources are needed for staff training and conducting or integrating research into RTSP operations. This is the only way to ensure that a RTSP keeps pace with advances in technology and science. To meet its full mission, the RTSP requires several critical positions to ensure that all necessary functions are accomplished. Positions include, but are not limited to: administrative, scientific, information and communication and technical personnel. Given the multilingual environment, the staff should be able to communicate in English and at least one more of the Caribbean official languages (Spanish, French, Dutch). The staff should be available to travel to all the ICG/CARIBE-EWS Member States.

Documentation Requirements

To be effective, the RTSP should have documentation that clearly states the centre's mandate, authority, and relationship to other government agencies. Equally important are references that document the centre's concept of operations, standard operating procedures, and agreements with partners and as requested by ICG/CARIBE-EWS.

RTSP Concept of Operations (CONOPS): this is a high-level document for decision makers and describes the system and how it functions in general terms. It should identify who is

involved and clearly define their roles and responsibilities. It should be maintained by the RTSP.

Operations Manual: this document details how the RTSP works to carry out its roles and responsibilities. The manual should be designed as an instruction manual to be used by the duty people at the centre. It should include information on emergency management plans and standard operating procedures (SOP), such as criteria for action, data streams, communications links, analysis software, messaging software, notification and dissemination methods, and general troubleshooting. It should be maintained by the RTSP. SOPs can be defined as:

- A set of written instructions describing routine, or repetitive, activities conducted by an organization. The instructions are stakeholder agreed-upon steps that will be used in coordinating the Who, What, When, Where, and How during an event.
- A mechanism for operating effective and reliable warning systems and disaster management systems. The RTSP SOPs must be linked at all levels from international to national and local warning institutions.

SOPs will include data processing, analysis and tsunami product dissemination procedures. SOPs also should facilitate good decision-making by describing in detail the actions taken by an agency to carry out its responsibilities, as defined in the system's Concept of Operations (CONOPS) document. The existence and use of SOPs are especially essential for rapid, efficient tsunami response since tsunamis are rapid-onset disasters with little time to prepare. Because of this, all responses need to be preplanned, well-practiced, and automatically enacted to minimize loss of life through quick notification.

Users Guide: this guide should contain general information for customers on tsunamis and the tsunami forecast procedures, and the criteria for action, along with sample messages and products (text messages, maps, tables). It should include a general description of that centre's system: seismic data, sea level data, RTSP message dissemination, public safety actions, and public responses. It should also include guidance on what the user or customer can expect from the tsunami service provider, including how to interpret messages for action, definitions of terms, and what to do when threat levels are issued. This document is formally agreed upon by Member States at ICG/CARIBE EWS meetings.

NTWC/TWFP/SRTSP Stakeholder Contacts: this document generally comprises contacts responsible for overall tsunami warning operations:

- These are Tsunami Warning Focal Points and/or National Tsunami Warning Centres for 24/7 action on tsunami emergencies,
- ICG Tsunami National Contacts (TNC) responsible for coordination,
- Sub Regional Tsunami Service Providers.

It is the responsibility of the IOC ICG/CARIBE-EWS Technical Secretary to maintain this list of designations by the Member States. It is the responsibility of the Member States to report any changes in designations and contact information on Tsunami National Contacts, Tsunami Warning Focal Points and Alternates to the IOC ICG/CARIBE-EWS secretary.

Tsunami Emergency Response Plans (TERP): RTSP must create and customize written Tsunami Emergency Response Plans to meet their specific needs. The documents form the basis on which to conduct routine drills to ensure response procedures can be effectively enacted by a 24/7 duty staff. These can range from stakeholder familiarization workshops, agency and multiagency drills, tabletop scenario exercises, and functional communications tests, to full-scale response agency field deployment exercises, which may or may not include

public evacuations. Documents and drills also ensure the consistency of actions as duty staff may turn over several times between actual tsunami events.

Capability and Interoperability Requirements of the RTSP

The RTSP needs to be interoperable within the basin and with other RTSPs, with the end goal being a fully interoperable tsunami warning system for the globe. RTSP should comply with the requirements which are based upon years of PTWC, JMA and NTWC experiences, and those edited by TOWS-WG working group:

1. Use the community standards magnitude scales (e.g. Mwp, moment magnitude from p waves)
2. Have the ability to determine rapid focal mechanisms and magnitudes using seismic data or other emergent vetted technologies.
3. Have real time access to pertinent data (e.g., sea-level, seismic, GNSS) to detect earthquakes and tsunamis and disseminate the corresponding products within 5 minutes of event detection time that could impact the AOC of CARIBE-EWS.
4. Maintain, have access to pre-computed tsunami models and/or run tsunami forecasts for the CARIBE-EWS AOC.
5. Be able to determine which Member State in the CARIBE-EWS AOC might be affected by a tsunami, and the threat level, based on standardized or otherwise agreed upon thresholds (earthquake magnitude and wave heights).
6. Revise their forecasts in light of additional seismic and sea level data or other data, e.g. GNSS.
7. Provide products in standardized format in accordance with global practices as approved by the ICG/CARIBE-EWS.
8. Transmit products on the GTS and e-mail in a timely manner, and have backup dissemination paths in place and tested.
9. Provide NTWCs, TWFPs and SRTSPs with estimated tsunami arrival times within five minutes of the event origin time and forecasted wave heights within 30 minutes of the event origin time.
10. Provide NTWCs, TWFPs and SRTSPs access to all RTSP products.
11. Coordinate with other relevant RTSPs when issuing products.
12. Coordinate end of threat messages with NTWCs, TWFPs and SRTSPs.

RTSP Key Performance Indicators

The RTSP will work with the Caribbean NTWCs and TWFPs to quantify its performance indicators (see table 3 for metrics targets). An annual report, as well as post event studies will be submitted by RTSP to the ICG/CARIBE-EWS. The RTSP performance indicators may include:

1. Elapsed time from earthquake or other trigger to issuance of tsunami products.
2. Accuracy of initial earthquake parameters (location, depth, magnitude) compared to the final solution from a reference agency.
3. Elapsed time to report tsunami wave heights, in the case that a tsunami is generated
4. Elapsed time to tsunami forecast.
5. Accuracy of tsunami forecast compared to in situ measurements in the case that a tsunami is generated.
6. Elapsed time to end of threat message in the event of no tsunami.

7. Reliability of RTSP office (power, computers, communications, 24/7 operations).
8. Metrics on communication tests.
9. Data availability (e.g. sea-level, seismic).
10. Up to date software and technology.

Table 1: Recommended Minimum and Optimal Requirements for Seismic Stations contributing data to the Caribbean Tsunami Warning System as agreed on the Meeting of Regional Seismic Network Operators of the Caribbean Basin Seismic Agencies (RSNO2), 25-29 February 2008 (revised from the list of criteria determined by Working Group I: Monitoring and Detection Systems, Warning Guidance), considering modifications approved at ICG-X.

CHARACTERISTICS	Primary network		Secondary network	
	Minimum req.	Optimal req.	Minimum req.	Optimal req.
Sensor type	Broadband	Broadband, accelerometer, continuous GPS	Short period	Broadband, accelerometer, continuous GPS
Station type	3 component	3 component	Vertical component	3 component
Accuracy of Location of Sensor	< 10m, horizontal < 10m, elevation	< 10m, horizontal < 10m, elevation	< 100m, horizontal < 20m, elevation	< 10m, horizontal < 10m, elevation
Calibration	Full response known to 10%	Full response known to 10%	System gain known to 10%	Full response known to 10%
Seismometer sampling rate	20 sps	20 sps	20 sps	20 sps
Seismometer frequency range (flat response)	0.1 – 60 sec	0.02 – 240 sec	Free period ≤ 2Hz	0.02 – 240 sec
Seismometer self noise	≤ 5 db below NLNM 0.1 – 10 Hz	≤ 10 db below NLNM 0.1 – 10 Hz	10 db above NLNM above 1 Hz	≤ 10 db below NLNM 0.1 – 10 Hz
Dynamic range	≥136 db	≥136 db	≥126 db	≥136 db
Absolute Timing Accuracy	<10ms	<10ms	<10ms	<10ms
Delay in Transmission to TWC	< 30 sec latency	< 30 sec latency	< 1 min latency	< 30 sec latency
Timely Data Availability	> 95%	> 95%	> 75%	> 90%
Data transmission protocol	Compatible with TWC	Low latency compatible with TWC	Compatible with TWC	Compatible with TWC
Data transmission	Cont / real-time	Cont / real-time	Cont / real-time	Cont / real-time
Communications	VSAT / Internet	VSAT / Internet secured transmission	Internet	VSAT / Internet
Infrastructure	Seismic vault	Thermally shielded vault	-	Seismic vault
Reliability	Problem investigation in less than 10 working days.		-	-
Energy autonomy	> 48 hours of autonomy (batteries backup)		-	-

Table 2. **Criteria and standards for the sitting, sensors, leveling procedures, data processing and other factors for sea level stations in the Caribbean, as approved by ICG-X**

CHARACTERISTICS	MINIMUM REQUIREMENTS	OPTIMAL REQUIREMENTS
Number of sensors with different technology	1	> 2
Transmitted sampling rate	< 1 min	< 15 sec
Recorded sampling rate	< 1 min	< 1 sec
Measurement accuracy	< 5 cm	< 2 cm
Maximum dynamic range	-	3 m above and below high/low tides
Data stored on site	-	yes
GTS transmission interval	< 15 min	< 5 min
GTS transmission redundancy	-	Data redundancy (ex : 10 minutes of data each 5 minutes)
Geodesic benchmarks	5 within few hundred meters	> 5 within few hundred metres + 1 on a national leveling network
Leveling periodicity	2 / year during first 2 years. Then each years	Idem + continuous GPS
Backup power autonomy	1 day	> 5 days
Timing accuracy	1 minute	Second or better (GPS)
Auxiliary sensors	-	Barometric pressure, wind ...
Station electronics altitude	-	> 5m
Continuous GPS specifications	-	< 30s sampling rate
Availability on VLIZ web site	yes	yes
Sensor drifts	-	No drifts

Table 3. **Key performance indicators**

Performance Indicator	Description	Target value
Reaction time	Time from the earthquake to the issuance of the first bulletin or from wave detection for non-seismic source events	< 5 minutes
Earthquake location	Difference between initial location and final authoritative location estimation	< 10km
Earthquake magnitude	Difference between initial magnitude estimation and final authoritative magnitude estimation	< 0.5
Earthquake depth	Difference between initial depth estimation and final authoritative depth estimation	< 10% of final depth or <5 km,
Tsunami forecast time	Time from the earthquake to the issuance of the first tsunami wave height forecasts	< 30 minutes
Accuracy of tsunami forecast	Difference between initial tsunami wave heights forecasts and measurements	< 15% of measurements or < 0.3m
Reliability of RTSP facility and tsunami services	Down time of the tsunami services due to any cause (power outage, communication problems, major observational data outage)	< 1 hour consecutive and < 1 day over the year
Up to date software	From time of latest update publication or ICG recommendation	< 1 year

References

U.S. Indian Ocean Tsunami Warning System Program, 2007. Tsunami Warning Center Reference Guide. Printed in Bangkok, Thailand U.S. IOTWS Document No. 26-IOTWS-07 Supported by United States Agency for International Development and partners, Bangkok, Thailand, 311 p.

von Hillebrandt-Andrade, Christa, 2013. Minimizing Caribbean Tsunami Risk, Science, Vol. 341pp. 966-968.

Mc Namara D.E., von Hillebrandt-Andrade C., Saurel J.M., Huerfano V. and Lynch L., Quantifying 10 Years of Improved Earthquake-Monitoring Performance in the Caribbean Region, Seismological Research Letters, January/February 2016

IOC/TOWS-WG and ICG/CARIBE-EWS reports

Acronyms

AOC	Area of Coverage
CONOPS	Concept of Operations
CTIC	Caribbean Tsunami Information Centre
RTSP	Regional Tsunami Service Provider
SRTSP	Sub-Regional Tsunami Service Provider
IOC	Intergovernmental Oceanographic Commission
NTWC	National Tsunami Warning Center
PTWC	Richard H. Hagemeyer Pacific Tsunami Warning Center
RTWC	Regional Tsunami Warning Centre
TERP	Tsunami Emergency Response Plan
TNC	Tsunami National Contact
CTWP	Caribbean Tsunami Warning Program
TWFP	Tsunami Warning Focal Point
TWS	Tsunami Warning System
TOWS-WG	Working Group on Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems

Appendix 1.

Brief example of staff positions for the RTSP's (taken from Tsunami Warning Center Reference Guide. Printed in Bangkok, Thailand U.S. IOTWS Document No. 26-IOTWS-07. Supported by United States Agency for International Development, NOAA and partners, Bangkok, Thailand.

RTSP Director/Deputy Director

The Director manages and provides oversight of the day-to-day operations at the centre. All operational systems, procedures, and products must be kept in operational status, and staff must be trained in proper response actions. Additional responsibilities include overseeing operational research, development of integrated computer and ocean modeling systems, community outreach and preparedness activities and maintenance of equipment necessary to support the tsunami warning system. The director is responsible for providing supervision and leadership to the TWC staff. The Director supervises the scientific staff that responds to

potentially tsunamigenic events and must be an expert in tsunami warning communications, real-time seismic analysis, tsunami dynamics, and tsunami history and forecasting.

Science Officer

The primary focus of the Science Officer is to ensure the scientific integrity of the products and services provided to the public by the centre, to lead or participate in joint research projects and developmental efforts and to implement new techniques and processes to the operational systems. Major duties include technology transfer/development activities, evaluation and improvement activities and serves on shift duty.

Warning Coordination Officer

The Warning Coordination Officer (WCO) plans, designs, executes and evaluates the overall preparedness programs. The WCO serves as the principal interface between the centre and the users of tsunami bulletins. The WCO should be responsible for planning, coordinating and carrying out the centre's area wide public awareness and tsunami readiness program, this would be in close collaboration with the CTIC. The WCO also leads and coordinates staff outreach efforts and provides direction, guidance, instructions and assistance to the staff regarding centre operational procedures. The WCO may also perform shift duty.

Operational Watch Standers

The Watch Stander must be able to make all observation, calculation, and interpretations using all available geophysical, oceanographic, and geographic data, obtained by diverse methods of communications, to locate and earthquake, determine its magnitude, evaluate its potential threat and issue with follow up, a tsunami product. The WS answers questions about geophysical events. The WS conducts applied research in Tsunami warning and forecasting systems. The WS will interact with participants of the CARIBE-EWS and is expected to be familiar with all its components.

Information and Communications Technology Officer

The Information and Communications Technology Officer analyzes and performs work necessary to plan, design, develop, acquire, document, test, implement, integrate, maintain or modify systems for solving problems or accomplishing centre work process by using computers. Assists in maintaining and enhancing the real-time seismic and sea level operational software. Does computer programming and software maintenance of the communication systems. Responsible for computer security.

Administrative Assistant

The Administrative Assistant performs a wide range of administrative functions for the staff management team including technical aspects of all administrative programs and activities for the office related to budget, funds control, purchasing, procurement requests, contract monitoring, property, vehicles, travel, training, personnel actions items, attendance, mail, office supplies and equipment, among others.