User's Guide for the
Central American Tsunami Advisory Center (CATAC)
– version 2025

Managua, Nicaragua
March 2025

Central America Tsunami Advisory Center (CATAC)

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Date: March 2025

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INETER, Managua, Nicaragua

NOTES

CATAC´s User´s Guide can be downloaded from
http://catac.ineter.gob.ni/doc/CATAC%20Guia%20de%20usuario%20SPANISH%2020190710.pdf

Comments and corrections

Please send comments and corrections to wilfried.strauch@yahoo.com .

Earlier versions

The first version of the *User´s Guide was elaborated in 1919. It was updated in December 2021 and 2023.*

This present version of 2025 of the User's Guide has been written with reference to the ***Common PTWS TSP Users' Guide Table of Contents*** *as prepared by the WG2 Task Team of TSPs in August, 2023; the TOWS-WG Global Services Definition Document from 2016 and the User's Guide for the Pacific Tsunami Warning Center (PTWS) Enhanced Products, IOC Technical Series No 1 05, revised edition. IOC 2014 are considered in the contents of this document.*

Contents

Executive Summary

This document was prepared for the use of the Civil protection agencies and the scientific institutions in Central America responsible for tsunami warning in their countries. They are the principal users of the products of the Central America Tsunami Advisory Center(CATAC). But the User´s Guide might be useful also for other stakeholders engaged in Tsunami hazard and risk mitigation and tsunami warning in Central América. The Guide is intended to provide the basic knowledge to understand the contents and possible applications of CATAC products. The concrete addresses of CATAC are at least those contacts contained in the list of recipients of tsunami messages maintained by the Tsunami at IOC/UNESCO in Paris and additional addressees in the countries of Central America. The products are available on CATAC´s website http://catac.ineter.gob.ni.

CATAC) has been established, in 2016, by the Nicaraguan government at the Nicaraguan Institute of Territorial Studies (INETER) in Managua, Nicaragua, responding to requests of the Central American countries. In the beginning the Functions of CATAC were realized by the Seismology Directorate at INETER with 10 staff supervised by an Advisor to INETER´s director and to the government. In the following years CATAC´s staff and its capacities increased remarkably. In Dezember 2024 the Nicaraguan government established CATAC as a new General Directorate at INETER assigning ample responsibilities on the national level for the Monitoring and Early Warning of Earthquakes and Tsunamis and confirming its functions as a sub-regional Tsunami Service Provider (TSP). The former Seismology directorate was completely integrated into the CATAC which now has a staff of 24. CATAC is part of both the Pacific Tsunami Warning and Mitigation System (PTWS) and the Caribbean Tsunami Warning System (CARIBE TWS), which operate under the governance of the IOC/UNESCO.

The technical capacities of CATAC for earthquake and tsunami detection and impact prediction and Warning were developed and strengthened, 2016-2019, in cooperation with JICA/Japan and IOC/UNESCO, including improvements of the seismic network. In a parallel project CATAC developed 2016-2023 together with the Swiss Seismological Service (SED at ETH/Zurich) the seismological processing capacities for Earthquake Early Warning. The experience, methods and products of these EEW systems can be used by CATAC for the fast evaluation of strong earthquakes.

Following the successful launch of the Pacific Tsunami Warning Center (PTWC) Enhanced Products and a series of ICG/PTWS recommendations, CATAC homologated its products in 2019 to provide recipient countries with the greatest utility through detailed tsunami hazard assessments for local coastal areas.
Following the approval of CATAC of ICG/PTWS XXVIII (04/2019) and confirmation by the 30th IOC General Assembly (06/2019), CATAC started on 22 August 2019 issuing the products in a pilot phase via email and TELEGRAM, and with its website. The introductory and familiarization pilot period of about 2 years duration -

1) increased CATAC's capacity for earthquake and tsunami processing and especially the training of 8 duty staff CATAC had additionally to the 8 originally assigned for 24x7 service;
2) supported training on the products and implementation of the necessary updates of the Standard Operating Procedure (SOP) in the recipient countries in Central America;
3) improved the instrumental capacity of the seismic networks in the region through the project for Earthquake Warning in Nicaragua and Central America (EWARNICA) with Swiss cooperation.

In November 2021, CATAC received the green light from the ICG/PTWS and in April 2023, from ICG/CARIBE-EWS to start an interim phase with the full and routine mode of work on both coasts of Central America.

To improve the efficiency of its products, CATAC started in 2023 an initiative with support from JICA/JAPAN to capacitate personnel from Central America countries on the methods CATAC is working with and to study the Standard Operation Procedures (SOP) which are used in the Central American countries for tsunami warning. In this project CATAC carried out a 17 Webinars and two presential courses of one week duration in Managua for this purpose. Besides the positive capacitation resyThe result was that most countries still use SOP edited in 1997 in a related UNESCO project. In this time CATAC had not yet finished its reinforcement phase what explains that CATAC is not even mentioned in some of the SOPs. Also, the new products of PTWC are not adequately used in the procedures and the responsibilities and the time frame for tsunami response after a warning was received is often unclear. All recipient institutions in Central America were visited to discuss this problem and CATAC will provide help to solve this problem

This User´s Guide contains short descriptions of the tsunami hazard and risk in Central America, about CATAC´s methods for earthquake detection and the related tsunami prediction, its products and provides related examples. In addition to the text-based products, additional graphical products with more information and levels of detail are also available. These include maps showing deep ocean tsunami amplitude forecasts, tsunami travel time forecasts, and expected maximum wave amplitudes in coastal areas of Central America.

1. Overview

1.1 Background

1.1.1 The development of CATAC's institutional basis

Historical origin Due to the experience with the disastrous 1992 tsunami on the Nicaraguan Pacific coast, the population and institutions of the country are much interested in the prevention and mitigation measures for tsunamis. In 1993, Nicaragua integrated the Intergovernmental Coordination Group of the Pacific Tsunami Warning System (ICG/PTWS) of the UNESCO and the Nicaraguan Institute of Territorial Studies (INETER) became the National Tsunami Warning Focal Point. In 1996, the seismology section of INETER started to function as the National Tsunami Warning Center (NTWC). The National Tsunami Warning System started to operate in Nicaragua already in 1996 combining the efforts of INETER for seismic monitoring and tsunami characterization and the warning and rescue capacities of the Civil Defense of the Nicaraguan Army. INETER emitted tsunami warnings on several occasions for earthquakes above magnitude 7.0, leading to ample evacuation measures. As in this time, INETER had not the capacity for a reliable prediction of the tsunami impact and false alarms occurred. In 1999, the National System for the Prevention of Disasters (SINAPRED was created, a network of all institutional and territorial structures relevant for disaster prevention and mitigation. In the following years Nicaragua become more and more active in the tsunami structure of the IOC/UNESCO.

The Intergovernmental Oceanographic Commission (IOC) of UNESCO adopted Resolution EC-XLI.6, for Member States around the regional seas, as appropriate, to actively promote the development, establishment and sustained operation of National and Sub-regional Tsunami Warning and Mitigation Systems.

The preparation of CATAC The ICG/PTWS in its XIX Session in 2003 decided to assist the Central American countries in the process to develop a regional tsunami warning system and established for this purpose the Regional Working Group on the Tsunami Warning and Mitigation System for the Pacific Coast of Central America (WG-CA). ICG/PTWS-XXV.1 recommended to determine whether El Salvador or Nicaragua (or both countries in cooperation) could establish an Interim Tsunami Warning Center to disseminate warnings to all Central American countries and the implementation of a Technical Committee for the Development of a Regional Tsunami Warning and Mitigation System. The following four ICG/PTWS-WG-CA meetings have developed the ideas for the Central American Regional Tsunami Advisory Center (CATAC): 1) Managua, Nicaragua, 04-06/11/2009; 2) San Salvador, El Salvador, 28-30/09/2011; 3) Managua, Nicaragua, 29/11/2014; 4) Managua, Nicaragua, 11/02/2019. The efforts for the establishment of a Central American Regional Seismic Network are documented in the materials Third Meeting of the ICG/PTWS-WG-CA.

The Center for the Coordination of Natural Disaster Prevention in Central America (CEPREDENAC) is the corresponding agency for disaster prevention within the Central American Integration System (SICA).
The Council of Representatives of CEPREDENAC at its meeting of February 6, 2015, decided to "recognize within CEPREDENAC's priorities the development of the Central American Tsunami Warning Center

(CATAC) and the creation of a Regional Seismic Network to be established in the Republic of Nicaragua and to elevate it to SICA". Also, the scientific or seismological institutions of all central American countries related to tsunami warning expressed their support for this proposal in letters sent to INETER.

It was important that, in 2011-2012, the SeisComP software system (GFZ-Potsdam, Germany) was adopted in all Central American seismological observatories for on line seismic waveform sharing, seismic data processing and dissemination. CATAC could benefit greatly from the long-standing and intense cooperation of Central American countries in seismology and seismic data exchange. To support the strengthening of tsunami warning and mitigation capacity in Central America, CATAC also would focus on regional collaboration and training by organizing training workshops on tsunami modeling and risk assessment and standard operating procedures.

The proposal for CATAC Nicaragua formalized at PTWS-XXVI in 2015 the proposal to establish CATAC in Nicaragua and to cover both the Pacific and Caribbean coasts under PTWS and CARIBE-EWS. Recognizing Nicaragua's remarkable progress in its National Tsunami Warning and Mitigation System and noting Nicaragua's offer to host and develop CATAC at the Nicaraguan Institute of Territorial Studies (INETER) in Managua, Nicaragua, ICG/PTWS - through Recommendation ICG/PTWS-XXVI.2. - accepted Nicaragua's offer to host and develop CATAC under the guidance of ICG/PTWS-WG-CA, within the framework of ICG/PTWS, ICG/CARIBE-EWS and TOWS-WG,

Appendix I of the Recommendation ICG / PTWS-XXVI.2 defines the Terms of Reference for a Central American Sub-regional Working Group on the Establishment of a Tsunami Advisory Center for Central America (TT-CATAC) for the purpose of "Assisting the Central American Working Group in the establishment of the CATAC until it has the capacity to provide operational services and the mandate "Under the guidance of the ICG/PTWS-WG-CA, the task team will strengthen coordination and cooperation among the CA countries to establish the CATAC".

The Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS) also accepted, in 2015, Nicaragua's offer to host and develop CATAC as a Subregional Tsunami Service (TSP) under the leadership of the PTWS Regional Working Group for Central America Pacific Coast and within the framework of ICG/PTWS, ICG/CARIBE-EWS and TOWS-WG. The 28th UNESCO/IOC General Assembly in 2015 noted Nicaragua's offer to host and develop a Tsunami Advisory Center for Central America (CATAC) under the guidance of the ICG/PTWS TT-CATAC, ICG/ CARIBE-EWS and TOWS-WG.

In 2015, the Nicaraguan government made the INETER responsible for the creation and operation of the CATAC. INETER, as a centralized institution of the Nicaraguan State is subordinated to the Presidency of Nicaragua. It is the largest geosciences institution in Central America (founded in 1982, recently around 400 co-workers). Its main offices are located in Managua, Capital of Nicaragua. INETER comprises actually the General Directorates (Departments) of CATAC, Geology and Geophysics, Meteorology, Water Resources, Geodesy and Cartography, Land Use Planning, Physical Cadaster, and Geoinformatics. The Geology Directorate of INETER combines the Volcanology and Geology Directorates.

Assignment as a General Directorate at INETER The Nicaraguan government redefined in December 2024 the structure of INETER and established CATAC as a General Directorate within the institution, merging the previously existing Directorate of Seismology into CATAC. Details of the structure of CATAC are to be defined during 2025. Preliminarily, CATAC comprises the Directorates of Seismology, the Early Warning Center, Monitoring Networks and Earthquake and Tsunami Engineering. CATAC is responsible for earthquake and tsunami hazard studies in Nicaragua and Central America, risk mitigation and early warning systems, maintains the Nicaraguan Seismic Network. CATAC fulfills the responsibilities of a Tsunami Service Provider (TSP) for Central America within the processes of the Tsunami Program of the Intergovernmental Committee (IOC) of the UNESCO. As such it is participation in the activities of the ICG/PTWS and the ICG/Caribe EWS. CATAC is directly subordinated to the director of INETER and CATACs General Director is an advisor to the director and the government of Nicaragua. CATAC's operations are covered by INETER's budget and in its development is considered in the annual and long terms planning for INETER.

The operation of CATAC, as well as its improvement, is a complex and ongoing process that involves the active participation and commitments of Member States through their respective agencies and institutions. The provision of CATAC tsunami advisory products is intended to enable the target countries (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama) to take appropriate actions against local and regional hazards, in collaboration with the provided by PTWC for the Pacific and the Caribbean Sea. The development of tsunami advisory products that take into account regional characteristics and the particular requirements of CATAC Member States is crucial for an effective regional tsunami warning and mitigation system. In this regard, strong involvement of all Member States in the development of CATAC regional products during the design period is very important.

CATAC's tsunami advisory products incorporate state-of-the-art forecasting skills, as real-time numerical modeling based on the fast CMT seismological solution. Numerical model benchmarking and validation of prediction results are essential. The CATAC tsunami advisory products serve as the basis for CATAC operation from 2019 onwards.

Mission and duties of CATAC as a TSP within IOC/UNESCO's Tsunami Program

Mission *C*ATAC's primary mission is to provide timely technical information on potentially destructive tsunamis to the National Tsunami Warning Centers (NWWCs) and Tsunami Warning Focal Points of the WG-AC Member States 24 hours a day, 7 days a week. To fulfill this mission, CATAC is prepared to continuously receive and process seismic and sea level monitoring data from within and outside the region and assess tsunami threats for CATAC member countries.

Duties CATAC's duties consist of the following elements:

1. Continuously acquire continuous seismic records from multiple sources in real time;
2. Detect and locate and determine the magnitude of all detectable earthquakes in and around the Monitoring Area.
3. Characterize earthquake source parameters through automatic and interactive processes;
4. Decide on the basis of seismological and geophysical information whether the earthquake could have generated a dangerous tsunami for Central America.

5. Calculate the estimated time of arrival (ETA) and tsunami amplitudes for the designated forecast points defined by the Central American countries;
6. Disseminate seismological and tsunami messages and bulletins to NTWCs and NTFPs;
7. Receive real-time sea level monitoring data from multiple sources to confirm tsunami generation and severity;
8. Conduct routine and unannounced communication tests with NTWCs and NTFPs;
9. Provide opportunities for education, outreach and training activities in the region;
10. Prepare a summary report each time a destructive tsunami occurs and messages are issued; Also prepare an annual report on CATAC activities for WG-CATAC; prepare publications in INETER's monthly and annual seismology bulletins. Develop and maintain the website catac.ineter.gob.ni.

1.2 Area of Service

CATAC's objective is to support the Central American countries in the prevention and mitigation of tsunami disasters. Therefore, the service areas for which CATAC issues products are the coasts of Central American countries and the islands of these countries in the Pacific Ocean and in the Caribbean Sea see the map in figure 1.

Figure 1. CATAC´s Service Areas on the Central American coasts of the Pacific Ocean and the Caribbean Sea

1.3 Earthquake Source Zone

CATAC Advisory information is issued when CATAC detects an earthquake of magnitude 6.5 or greater in its Monitoring Areas (see Figure 2). To fulfill its duties CATAC must monitor not only the areas near the coasts of Central America but also more remote areas. As CATAC's Monitoring Areas are characterized as those areas that contain tsunami sources from which waves can reach some point in the Service Areas, i.e. the coasts of Central America, within about one hour of being generated. These areas are limited by polygons as follows:

1) The Pacific zone: starting from the border of the Mexican states of Guerero and Oaxaca along the coasts of Oaxaca, Central America, Colombia and Ecuador, then from the border of Ecuador with Peru a line to the Southern tip of Galapagos Islands, from there continuing a line back to starting point at the coast of México.

2) The Caribbean zone: starting from Cancun (Mexico) along the coasts of Mexico, Belize, Central America, Colombia, Venezuela until the town of Coro (Venezuela), then a polyline passing Santo Domingo (Dominican Republic), Inagua Islands (West Indies), Trinidad (Cuba), and back to Cancun (México). In the SeisComP processing system the polygons are defined numerically from coordinates.

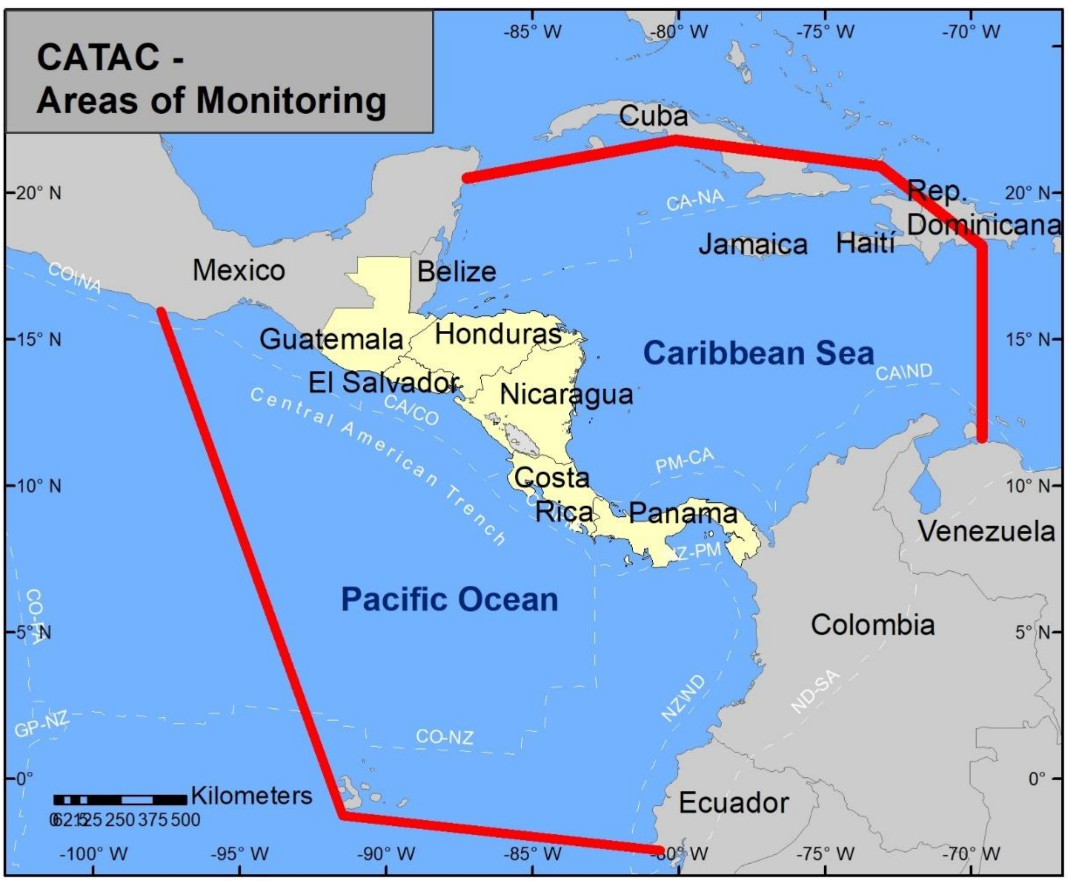

Figure 2. CATAC´s Monitoring Areas in the Pacific Ocean and the Caribbean Sea

Seismicity of Central America In CATAC´s Area of Monitoring The principal tsunami hazard for Central America arises from local earthquakes mainly in the Central American Subduction Zone from Southern Mexco to Northwestern Panama which may generate earthquakes up to magnitude 8.6. Not only the strong magnitudes of the earthquakes but also the short time between detection of the seismic event and the tsunami impact at the coast

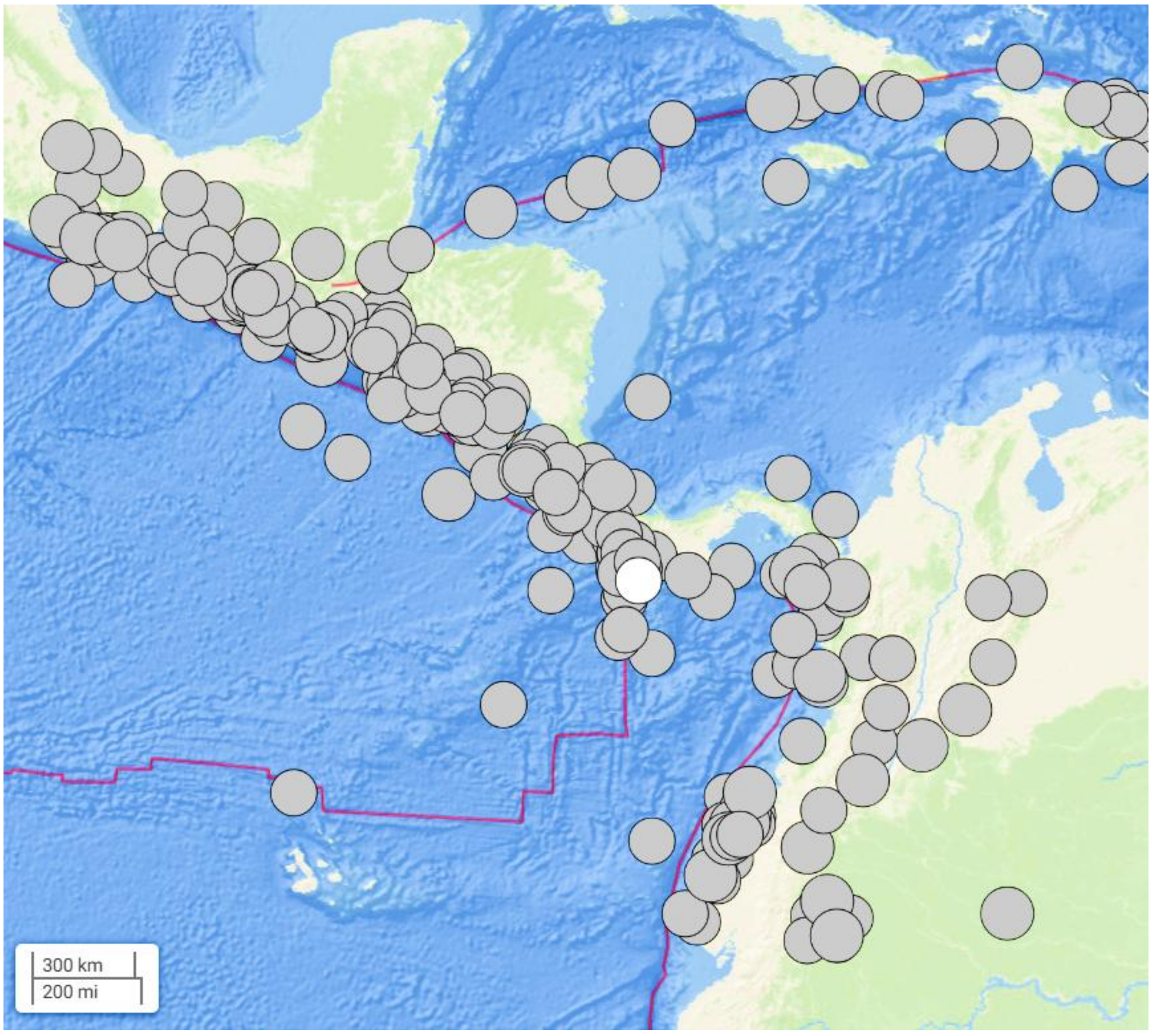

Figure 3. Earthquakes 1904-2025 with magnitudes above 6.5 in and around Central America. according to NEIC/USA. Large earthquakes occur mainly in the Central American subduction zone from Guatemala to Southern Costa Rica

Volcanoes in Central America The volcanic hazard is high in Guatemala, El Salvador, Nicaragua and Costa Rica but much smaller in Honduras and Panama.

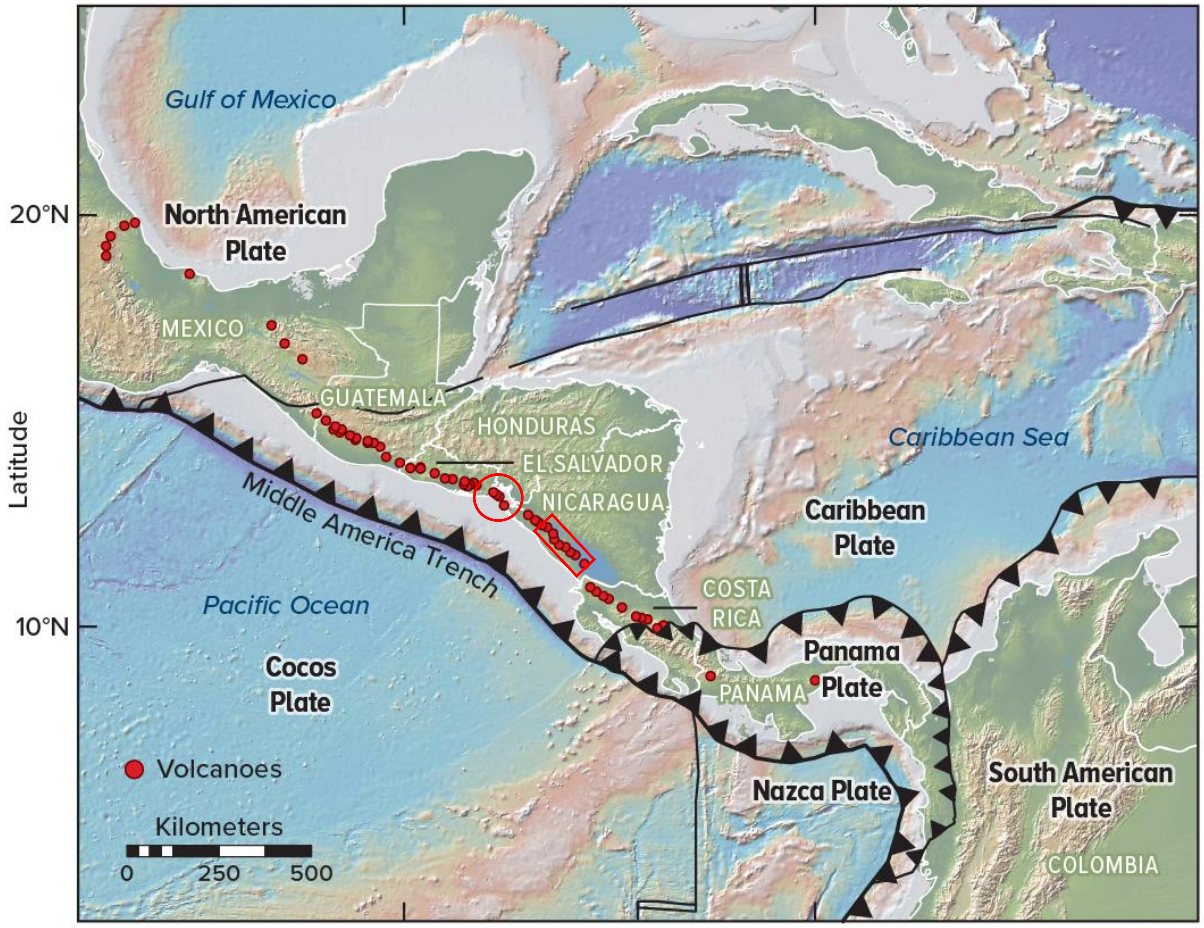

Figure 4. Central American Volcanic Arc

Volcanoes can cause tsunamis the Fonseca Gulf (Pacific coast, red big circle) and in the big lakes of Nicaragua (red rectangle) . *Taken from https://knowablemagazine.org/content/article/physical-world/202/central-american-volcanoes-clues-earth-geological-evolution*

1.4 Tsunami Hazard

General tsunami hazard The Pacific Coast of Central America is prone to tsunamis (Figure 1) due to the high seismicity (Figure 2) at the margins of the Cocos and Caribbean tectonic plates; while the Caribbean Sea Coast of this region has a considerably lower tsunami threat (Molina, 1996; Fernández et al., 2001; IOC 2018). The largest known tsunami impact in history was caused by the 1992 disastrous event on the Pacific coast of Nicaragua with a runup of up to 10 meters.

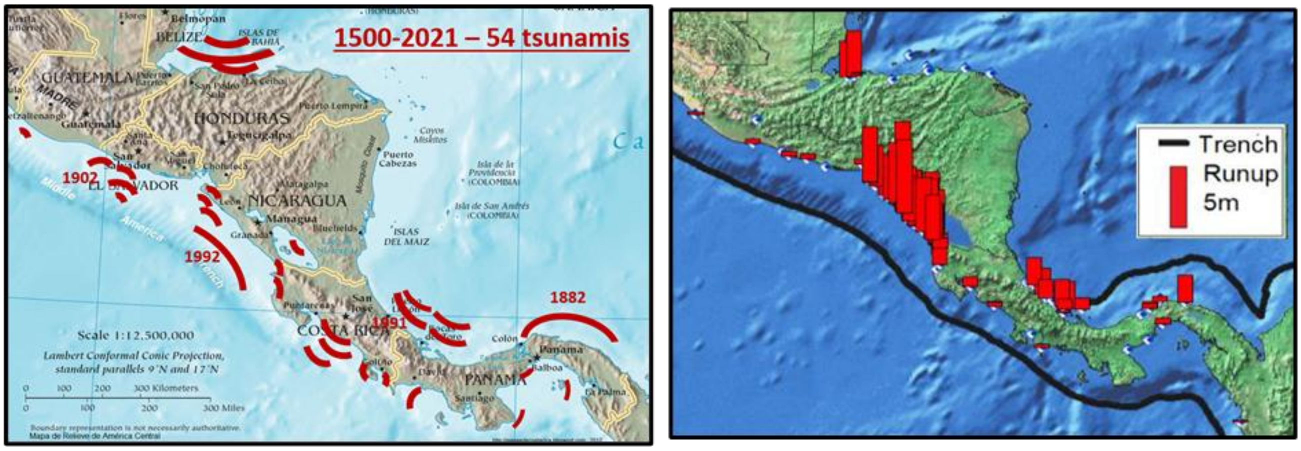

Figure 5. Location of tsunamis (left) and runup (right) in Central America since 1500.
Source: Molina, 1996; Fernández et al.,2000); NGDC/WDS, 2015; modified**.**

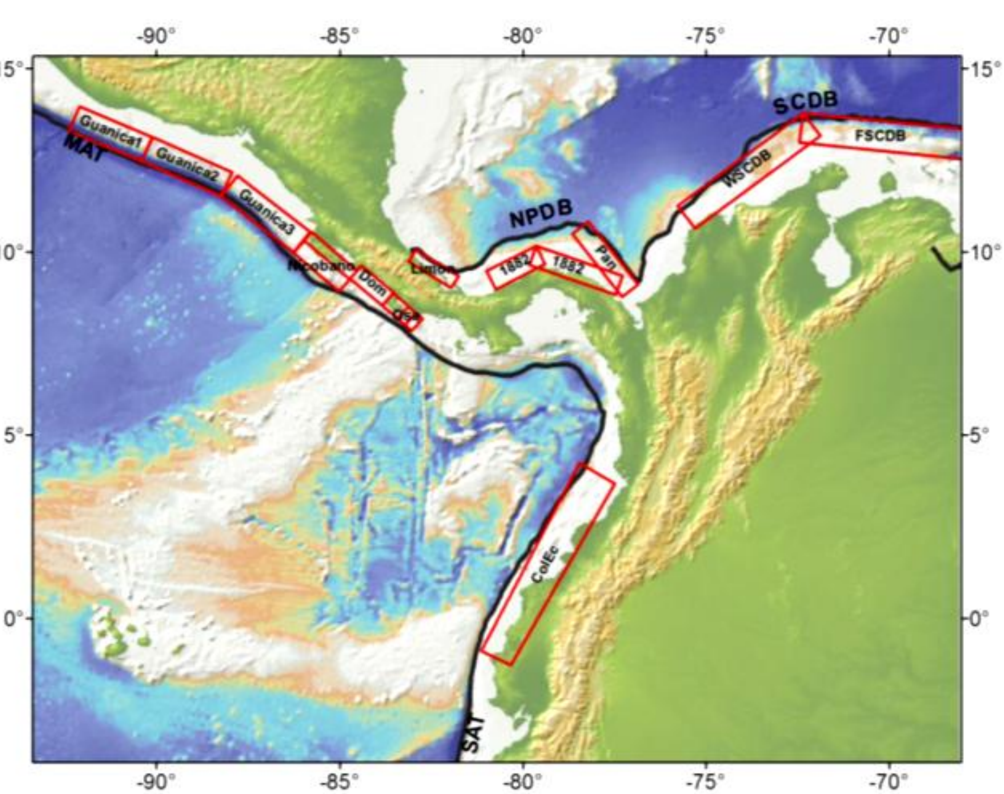

Figure 6. Major earthquake sources contributing to the tsunami hazard for Central America (red rectangles). According to IOC (2018), IOC (2020).

In the Pacific Ocean, Guatemala, El Salvador and Nicaragua have a very broad continental shelf with shallow sea depth, which reduces wave speed and increases the time tsunamis need to reach the coast. On these coasts, tsunamis would enter within 30 to 60 minutes after the local earthquake. However, in some coastal areas, the minimum time of impact of local tsunamis is much shorter, which forces CATAC to send warning messages within a few minutes.

Coastal areas with reduced tsunami first impact time In many parts of the Pacific and Caribbean coasts of Central America there exists a wide shelf area between the main earthquake source area and the coast. In these areas, the delay between the earthquake occurrence and the tsunami impact is rather large, between 30 or 60 minutes or even larger.

But there exist coastal zones with reduced time to tsunami impact exist, due to:

1) The source area is very close to the coast: e.g. Swan Islands in Honduras, Nicoya and Osa in Costa Rica; Chiriqui Gulf, Azuero and Darien in Panama).

2) The source fault enters the coast: e.g. Northern Guatemala, San Juan del Norte in Nicaragua, El Limon in Costa Rica).

3) Between the coast and the source zone there are very deep waters (e.g. Gulf of Chiriqui in Panama).

4) There is a deeper sea channel that connects the source zone with the coast (e.g. Southern Guatemala, Gulf of Chiriquí in Panama).

These conditions exist also combined in some areas.

Figure 7. Areas where the tsunami impact time can be less than 10 minutes (red lines)

Volcanic tsunami hazard in the Gulf of Fonseca, Pacific coast The Gulf of Fonseca, shared by Nicaragua, El Salvador and Honduras, seems to be the only place along the Pacific Coast of the Americas - besides Alaska and Southern Chile - where volcanoes are situated at the very coast and thus with the possibility to generate tsunamis due to flank collapses, landslides, lahars, pyroclastic flows and volcanic explosions. (Not to count volcanoes Barcena and Evermann on the Revillagigedo Archipelago more than 600 km west of the Mexican Pacific coast (Puerto Vallarta) or other Volcano islands far from the main land) The huge eruption in 1835 of Cosiguina volcano, Gulf of Fonseca, Nicaragua, possibly caused tsunamis, but there are no direct evidences. In this time the population density in this area was very low. Besides Cosiguina there is Conchagua, a large inactive volcano on the coast of El Salvador. Both, Cosiguina and Conchagua, could cause tsunamis due to flank collapse or lahars. In the Gulf there are several volcanic islands and earthquakes with magnitudes up to 6 have occurred, also seismic swarm activity is frequent.

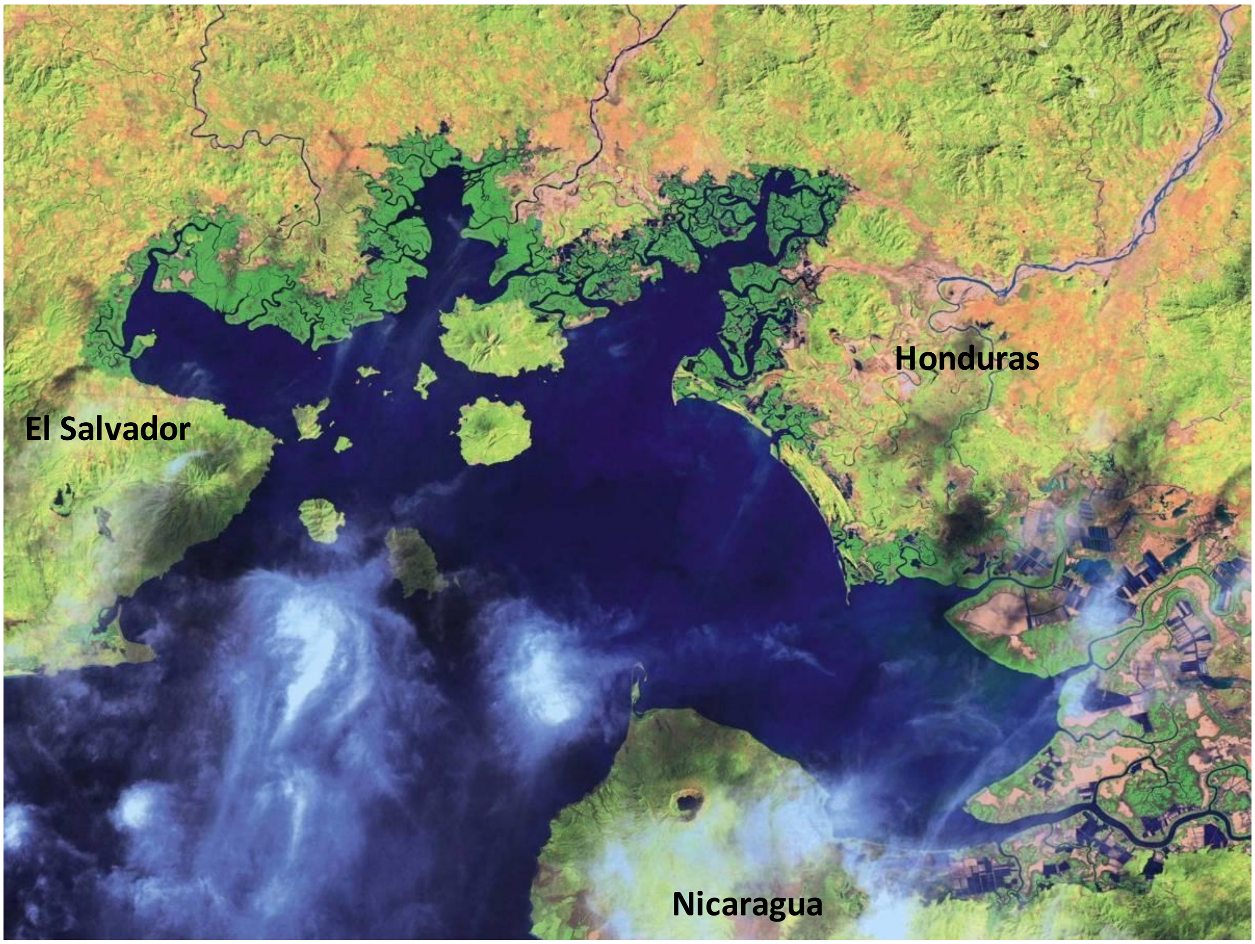

Figure 8. Gulf of Fonseca. Satellite photo. Wikipedia

The Gulf of Fonseca is included in CATAC´s area of monitoring and area of responsibility. CATAC/INETER is in discussion with the seismic networks of El Salvador and Honduras to improve the seismic monitoring for the Gulf and to develop also the capacity for tsunami warning in the case of volcanic sources.

Tsunami hazard in the big lakes of Nicaragua There exist geological and historical information on the occurrence of tsunamis or seiches in the big lakes in Nicaragua caused by earthquakes or volcanic processes. The tsunami catalogue of Central America (Molina, 1997) mentions that in May, 1844 an earthquake with a magnitude between 7 and 7.8 with epicenter in the southernmost part of Lake Nicaragua of Nicaragua caused a tsunami o seiches in the Lake.

CATAC has carried out tsunami simulations of large earthquakes in the area between Nicaragua and Costa Rica and for earthquakes in the Pacific Ocean which confirmed that tsunamis or seiches with amplitudes of several meters can occur in Lake Nicaragua due to these events.

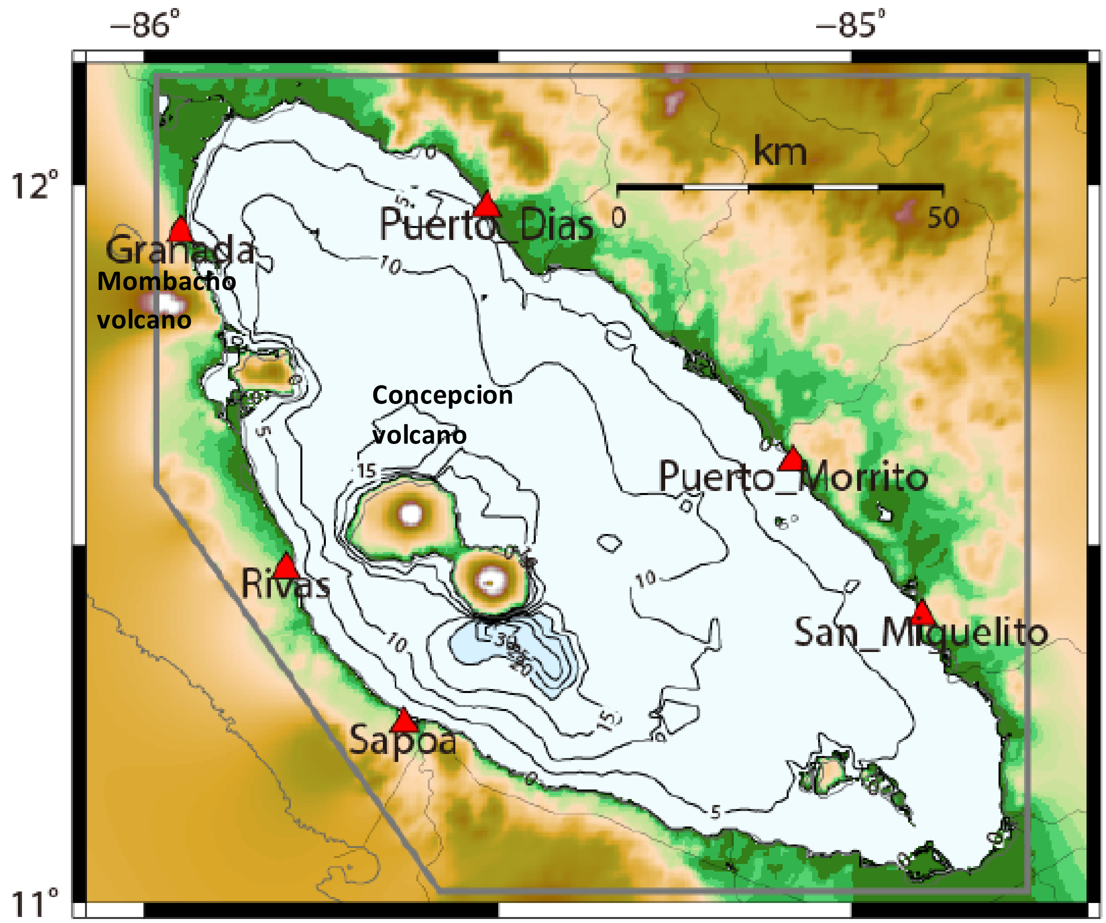

Figure 9. Map of Lake Nicaragua. Red triangles indicate coastal sites used for tsunami modelling. Bathymetry in meters.

For Mombacho, a steep volcano located at the coast of Lake Nicaragua very near the city of Granada, there exist geological and topographic evidence for a large collapse of its Eastern flank. The landslide entered directly into lake Nicaragua and created a peninsula and hundreds of small islands. Certainly, this event caused a tsunami in the lake. At this volcano another collapse is known which also might have entered the lake (Shea et al, 2008).

Concepción, a steep active volcano on Ometepe Island in Lake Nicaragua, could also be the origin tsunamis caused by landslides, pyroclastic flows or volcanic explosions. Perez (2019) has carried out numeric simulation of tsunamis caused by a debris avalanches at Concepción and Mombacho. It was shown that destructive tsunamis could not only affect the vicinity of these volcanoes but also at other densely populated coasts.

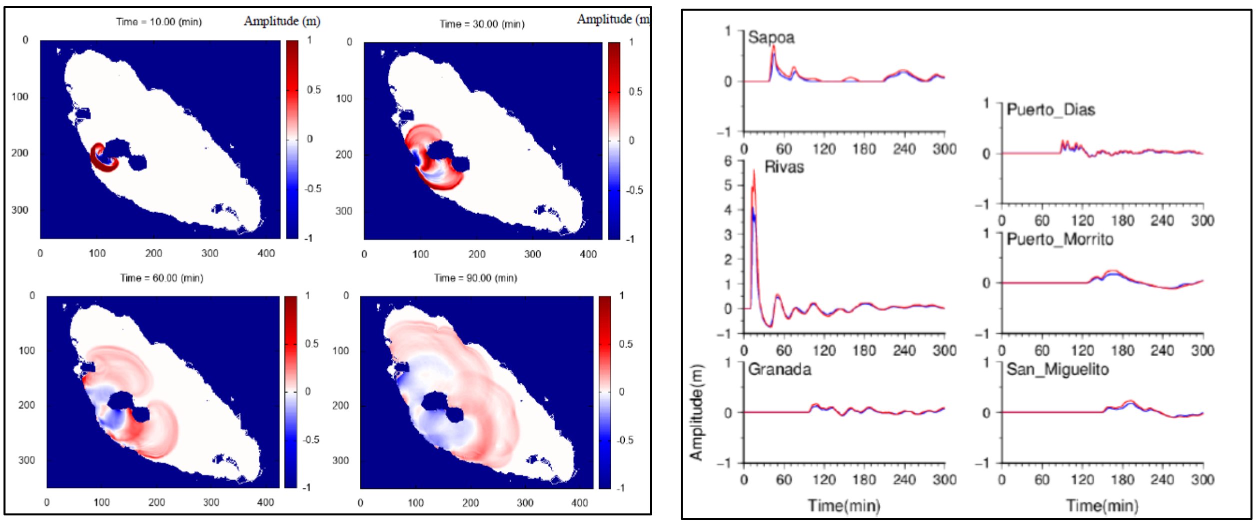

Figure 10. Tsunami simulation for Lake Nicaragua.

Left: Snapshots of simulated tsunami propagation from a debris avalanche at Concepcion volcano; Right: Simulation of the tsunami impact at coastal place of Lake Nicaragua. From Perez (2019)

Freundt et al (2006ª, 2006ᵇ), documented geologic evidence about a tsunami generated by a volcanic explosion near Apoyeque volcano located at the shore of Lake Managua, only 8 km from the Nicaraguan capital, Managua. Freundt et al (2007) discuss the possibilities of tsunamis generated by volcanoes. The Momotombo, another active volcano in Lake Managua, could also cause tsunamis due to pyroclastic flows or flank collapses.

Meteorological tsunamis

The Caribbean coast of Central America is affected by hurricanes and other meteorological phenomena which can swell the surface of the sea which then propagate to the coast similar as tsunamis and can reach several meters height on the beach. Also, the big lakes in Nicaragua can be affected by these meteorological tsunamis, when strong air pressure disturbances travel over the lakes with velocities similar as the tsunami propagation speed corresponding to the shallow water depths in these lakes, mainly 10 to 20 meters, in smaller areas up to 40 meters. In the moment CATAC has no capacities to monitor and process these phenomena but related discussions are going with the INETER meterological Department.

Not to be confused with the tsunamis are the strong surfs which affect frequently certain places on the Pacific coasts of Central America (e.g. Cedeño/Honduras, Corinto/Nicaragua) and which are caused by distant storms or hurricanes in the Ocean from where the generated waves travel to the coasts. The monitoring of theses waves and predictions of possible impact are done by the for oceanographic groups in some countries of Central America as for instance at MARN in El Salvador.

2. Operations

3. CATAC´s Capacities and Facilities

2.1.1 CATAC´s staff

CATAC operates with a dedicated team of 24 professionals (see list below) to ensure continuous 24/7 monitoring and warning services for various phenomena. The team works in two 12-hour shifts per day, maintaining seamless operational coverage. Since November 2019, CATAC has been mandated to always have a minimum of two personnel on duty.

The staff has undergone extensive training, initially through the JICA project (2017–2019) and subsequently in ongoing capacity-building initiatives. Both watch standers remain stationed within CATAC's facilities, with additional emergency support available from INETER during office hours.

To strengthen its operational framework, CATAC has designated five key leadership positions:
-General Director of CATAC
-Director of Seismology
-Manager of the Monitoring and Warning Center
-IT Manager for CATAC
-Manager of CATAC's field stations in Nicaragua.

For sustained operations, INETER's Computer and Network Division provides technical assistance in computing, local networking, and internet connectivity whenever CATAC's internal capacity requires additional support.

To foster regional collaboration, CATAC Member States are strongly encouraged to nominate seismologists or tsunami specialists for temporary assignments at CATAC. These assignments would facilitate bilateral cooperation, promoting the exchange of expertise and personnel. In 2024, one seismologist from the University of Honduras has made use of this possibility in a one week visit to CATAC.

List of CATAC staff, as of March 2025

D - serves as a 24x7 on-duty seismologist

(D) – capacitation ongoing for 24x7 on-duty seismologist

DG – serves as 24x7 on-duty for immediate advice to government

P – assignment pending

#	First and last name	24x7	Function / experience
1	Dr. Wilfried Strauch	-	General Director CATAC; Advisor to INETER and Government of Nicaragua
2	MSc Emilio Talavera	D	Director of Seismology; seismology, tsunami; scripting
P	NN, to be assigned	D	Director of the Central Monitoring Center; seismology, tsunami, volcanic seismology, volcano seismology
P	NN, to be assigned	D	Director of seismic and geophysical network; seismology, tsunami, electronics, communications
P	NN, to be assigned	D	Director for engineering aspects of earthquake and tsunami warning
3	Eng. Miguel Flores	D	IT expert, Computer science, digital systems, Seismology, Tsunami, IT maintenance
4	MSc Greyving Argüello	D	Seismology, Geophysics, Tsunami
5	MSc Amilcar Cabrera	D	Seismology, Mathematics, Tsunami, porgramming
6	MSc Petronila Flores	D	Seismology, Geology, Tsunami, Publication of CATAC monthly and yearly bulletins
7	MSc Martha Herrera	D	Seismology, Electronics, Tsunami, Digital Communication, Seismometry, Sea gauges
8	MSc Domingo J. Ñamendi	D	Seismology, Electronics, Tsunami, Digital Communication, Seismometry, Sea gauges
9	MSc Ulbert Grillo	D	Seismology, Tsunami, Electronics, Digital Communication, Seismometry
10	MSc Ana Rodriguez	D	Seismology, Tsunami, GIS
11	MSc Milton Espinoza	D	Seismology, Tsunami, GIS
12	MSc Wesly Rodríguez	D	Geophysics, Seismology, Tsunami
13	Eng. Norwin Acosta	(D)	Tsunami Modelling, GIS
14	Eng. Jaqueline Sanchez	D	Seismology, Tsunami, IT, Contacts with Users
15	Eng. Elvis Mendoza	-	Electronics, Seismic and GPS equipments
16	Tec. Allan Morales	D	Seismometry, Tsunami, Electronics
17	Tec. Antonio Acosta	D	Seismometry, Tsunami, Electronics
19	Tec Leonel García		Electronics, Field assistant
20	Michael José Malespin	DG	Informatics
21	Carlos José Pérez	DG	Civil Eng
22	Geovanny Rivas	DG	Informatics
23	Juan Carlos Reyes	DG	Economist
24	Ileana Boza	-	Administrative Assistant
P	N.N. free position	-	Programmer

Free Consultant: Eng. Gerzon González (SeisComP programming, IT)

2.1.2 CATAC´s Facilities

Monitoring and warning room CATAC´s Monitoring and Warning Center for earthquakes, tsunamis, seismological evaluation of volcanic phenomena and landslides occupies an area of 250 square meters divided in a monitoring and warning room, a meeting room, an underground bunker for seismographs, computational servers bunker and battery backup, the electronics/seismometry lab for maintenance of the data center and Nicaraguan seismic network , an IT room, and 6 offices for CATACs personnel.

Computing facilities CATAC is equipped with high performance servers, workstations, communication hardware, as well as decision support systems, facilities for the development and maintenance of equipment at the central and monitoring stations throughout Nicaragua. Critical equipment and facilities have multiple safety redundancies for the case of fatal failure.

Most of the servers are located in a concrete bunker of about 40 square meters in the basement of the building where there are also the seismometers, accelerometers for routine and instrument tests. There is also a battery backup unit with a capacity of 20kWh. The bottom of the bunker is at about 3 m depth below surface.

Photo 1. Server and Seismometer bunker at CATAC.

Around the processing facilities the is ample room for meetings, capacitation and emergency work (situation room). That way the watch standers - to some extent - can participate in meetings or capacitation measures, while there are no important events occurring.

Part of CATAC is also a laboratory for maintenance of seismic, electronic, communications devices and for testing seismic equipment.

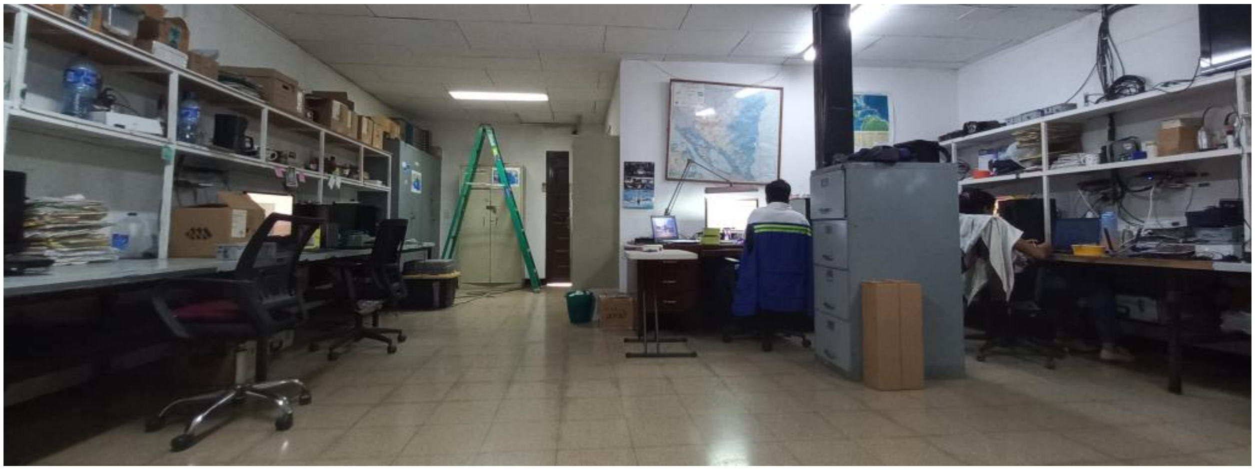

Photo 2. Seismometric and electronic laboratory

Computing facilities The main workstation for automatic and manual seismological and tsunami processing was since 2017 a machine which has an Intel Processor Xeon (LGA2011-3 2.60G 35M Proc E5-2697V3 14C DDR4 Up to 2133 MHZ) and a GPU Nvidia TESLA M40 GPU 12GB GDDR5. Additionally, there are now 2 more modern workstations installed with NVIDIA RTX 4090 GPU which reduced considerably the computing time for tsunami simulations.

Photo 3. CATAC, Processing and Alerting Room

Photo 4. CATAC, Situation and Meeting Room

Photo 5. Seismologists of the 24x7 service. They revise the automatic results, perform the manual processing and must publish the first manual results within 2 minutes after the detection of the earthquake.

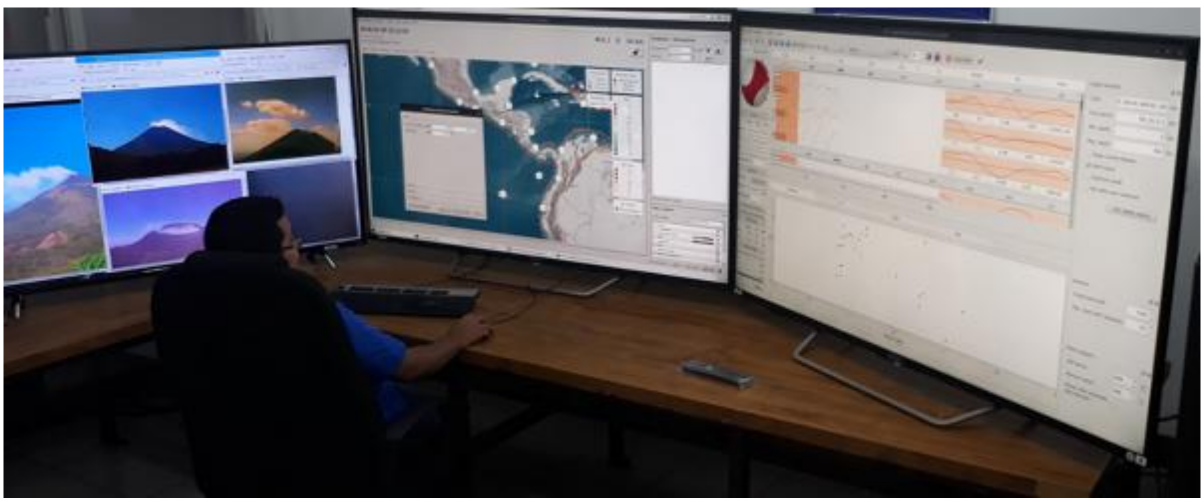

Photo 6. Moment Tensor calculation and numerical tsunami simulation are important tasks of the CATAC seismologist on duty.

Backup facilities of CATAC The most important parts of CATAC's operating system - as the workstation for earthquake and tsunami processing and the terminals for manual processing and the electric power backup systems - are duplicated in case of partial malfunction. However, the possibility of catastrophic failure cannot be eliminated; a giant distant earthquake or a local earthquake in Managua might affect CATAC facilities. If CATAC products cannot be issued in an emergency, CATAC user countries/organizations should take appropriate measures with reference to PTWC products and/or use their own or alternate means to estimate the effects of a strong earthquake possibly generating tsunami advisory services for both coasts of Central America are currently provided by the Pacific Tsunami Warning Center (PTWC).

Backup center for CATAC, in Nicaragua CATAC has a plan for the implementation for a backup center in Nicaragua. The site under consideration is located in a facility of the Nicaraguan Electric Power Transmission Company ENATREL near the town of Sébaco, about 100 km N of Managua. This place is distant to the volcanic chain of Nicaragua, has much lower seismic hazard, would not be seriously affected by earthquakes in Managua or in the Nicaraguan subduction zone. ENATREL provides access to their optical fiber network which transports large part of the data of the Nicaraguan seismic network. ENATREL is also an INTERNET provider and would facilitate access to the regional and international seismological data centers.

Backup center for CATAC, in El Salvador Another backup plan is under discussion with the Seismological Center at the Ministry of Environment in El Salvador (MARN). INETER and MARN are cooperating closely and MARN is the NTWC of El Salvador. They dispose to similar facilities and software system as CATAC and their organization of earthquake and Tsunami processing is similar. MARN does not use the complete suite of SeisComP, as CATAC does, but has elaborated own solutions for the most important functions. In talks between CATAC and MARN a closer integration of both centers was agreed, including direct exchange of the products of both centers using the corresponding modules of SeisComP.

2.2 Seismological and Geophysical Monitoring Networks

2.2.1 Seismic stations

CATAC´s Seismic Network in Nicaragua CATAC, besides working as a TSP within the IOC/UNESCO system, on a national level is responsible to develop and to maintain the Nicaraguan seismic network which currently (2025) has around 140 accelerometric, short period and broad band seismic sensors The data are received by direct streaming with the seedlink protocol and is fed into several SeisComP systems for archiving and for real time automatic and manual processing. About 70 % of these stations were installed since 2016 that means with the direct consideration to be used for the reinforcement of CATAC and the development of the earthquake early warning system in Nicaragua. The network uses many low cost instruments (for example Raspberry Shake) according the limited budget of INETER. But there are also sufficient broad band sensors suited for some tsunami specific processing methods.

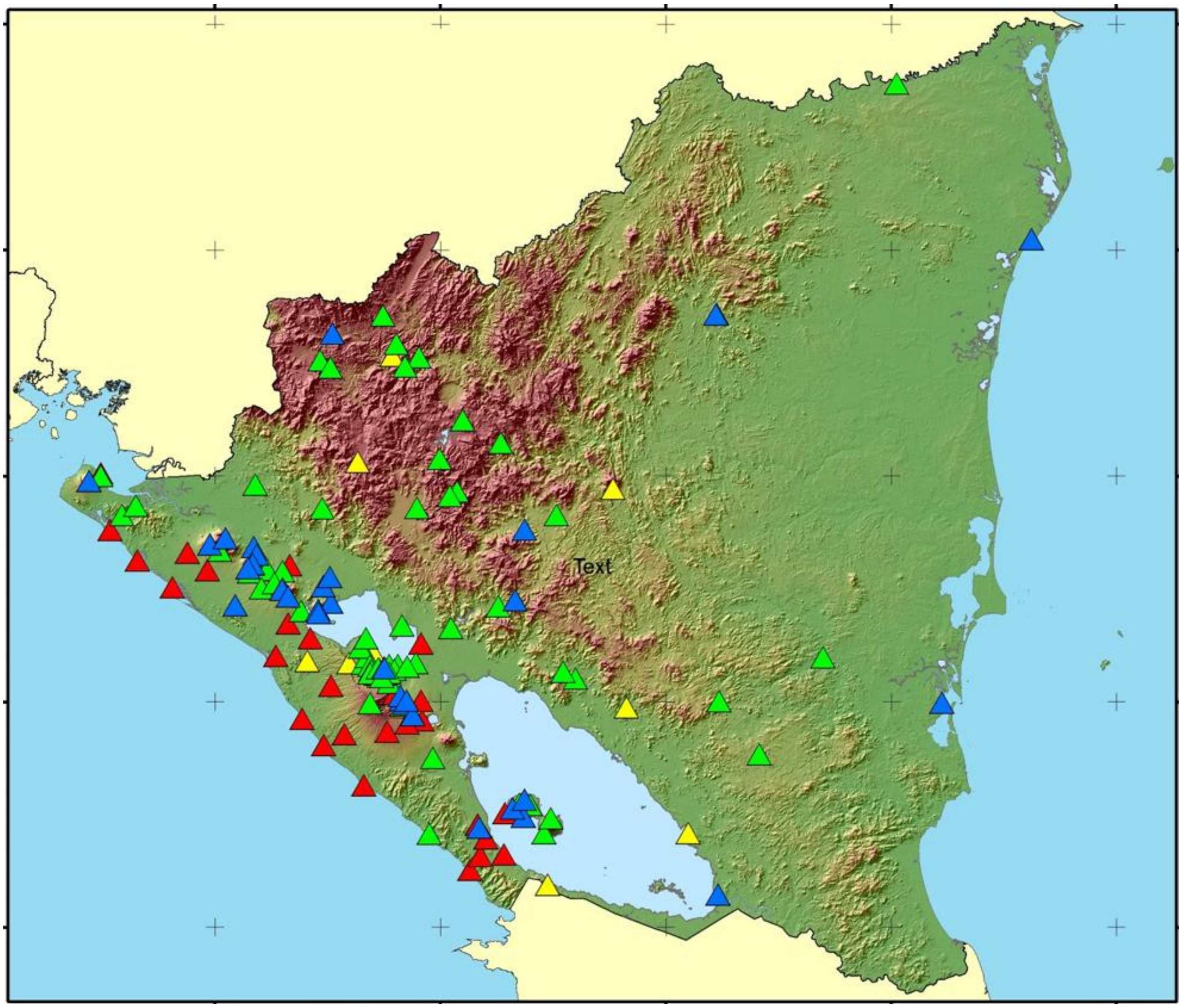

Figure 11. CATAC´s existing seismic network 2025

In 2025, CATAC´s seismic network will be significantly expanded. SINAPRED is executing with support from China the project SINAREM on the improvement of the Disaster Prevention in the country. There will be purchased 50 accelerographs, 36 broad band sensors, 36 Raspberry Shake sensors and 7 infrasound instruments which will be installed by CATAC´s personnel in 2025 and 2026..

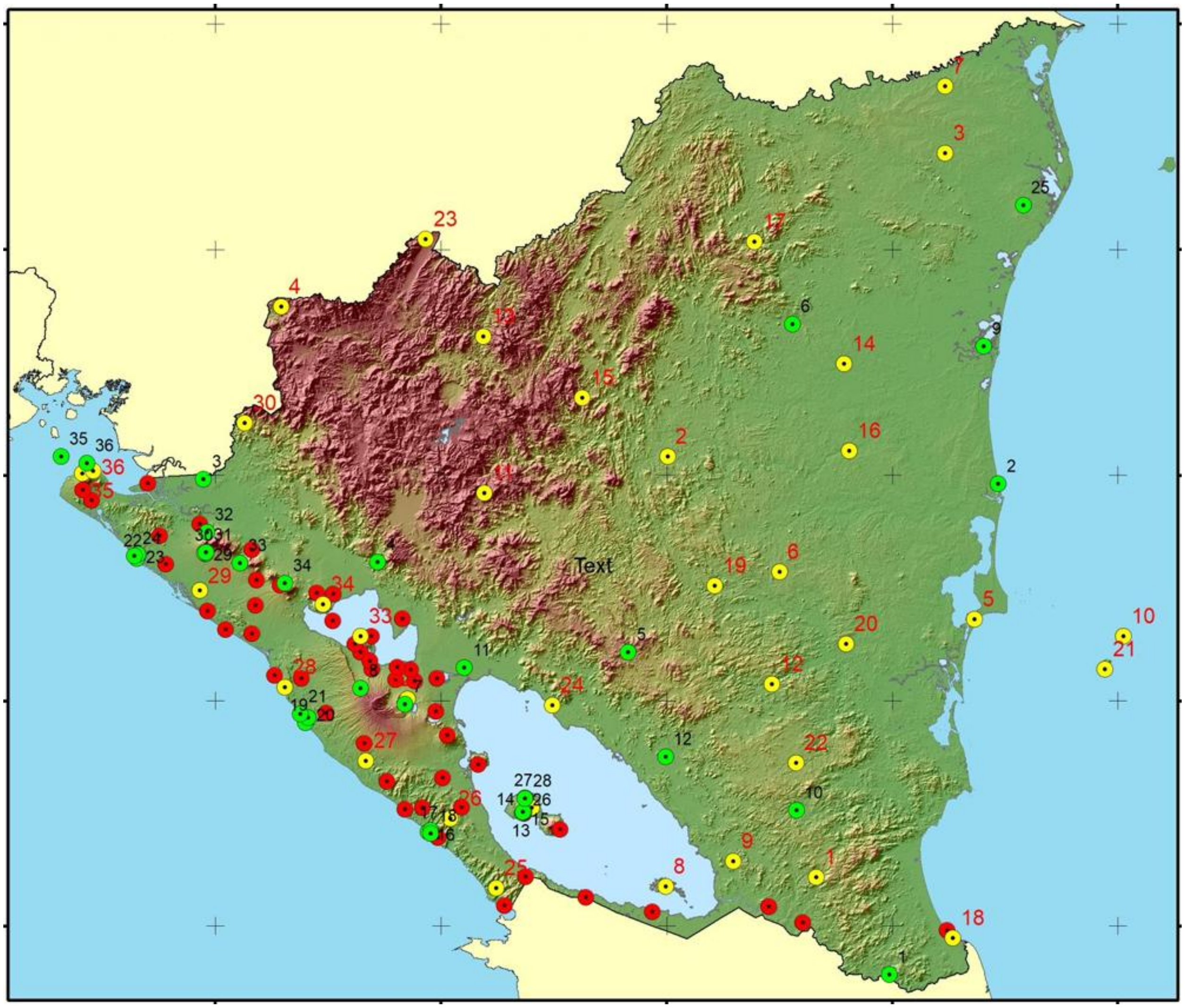

Figure 12. New stations for CATAC´s seismic network provided by the SINAREM project, 2025-2026

Seismic networks in other Central American countries CATAC receives real time data from nearly all seismological data centers in the countries of the Central America. These data obtained via direct transmission via seedlink from the corresponding network centers are characterized by a low delay of the data transmission from the station to CATAC, normally less than a few seconds. Obviously, it is the responsibility of the countries interested in receiving CATAC's tsunami advisory to provide the necessary data. If a country does not provide sufficient data, it will not be able to receive the products quickly and in good quality, especially for local events near its coasts.

Table 1. Direct streaming from Central America, low delay (several seconds)

Country	Institution	Type of sensors	Number of seismic stations
Nicaragua*	CATAC/INETER*, Governmental	ac, sp, bb	140
El Salvador*	MARN*, Governmental	ac, sp, bb	70
Guatemala	INSIVUMEH*, Governmental	ac, sp, bb	60
Honduras*	COPECO*, Governmental	sp, 1 bb	15
Honduras*	UNAH*, University	Sp	16
Costa Rica	OVSICORI, University	ac, sp, bb	10
Costa Rica	UCR, University	sp, bb	22
Panama*	Panama Canal*, Governmental	ac, sp, bb	10
Panama*	Baru Network, Private	sp	8
Panama*	IG-UPA*, University	ac, sp, bb	6
*) All existing networks in the country participate	*) Facilitates complete network Gob-Government, Univ.-University, Priv.-Private		**Total 357 (2025)**

CATAC receives also data form other countries in its Region of Monitoring as listed in the following table:

Table 2. Direct streaming from countries in the greater region,

Country	Institution	Type of sensors	Number of Seismic stations
Mexico (Southern part)	UNAM, University	bb	14
Venezuela	FUNVISIS, Government.	bb	11
Colombia	Colombian Geological Service (SGC), Governmental	bb	21
Ecuador	Geophysical Institute, IGN, University	bb	20

Other broad band seismic data from South America, North America, the Caribbean and the World come in through EarthScope (previously IRIS)/USA or GEOFON (GFZ, Potsdam, Germany).

The density of seismic stations in Central America is generally very high, which facilitates the rapid and accurate elaboration of CATAC products for local earthquakes occurring in the region. The governmental seismological institutions in Nicaragua, El Salvador, Guatemala and Honduras facilitate the data of 100% of their networks. However, in Honduras and Panama there is still insufficient coverage for high quality products especially there is a lack of broad band sensors and there are currently only one stations near the plate border North of Honduras which produces the major seismic hazard for the country. As for Panama, CATAC is in the process of establishing an agreement with the University of Panama (UPA) to receive more seismic data from its Geosciences Institute.

The high density of seismic stations and the small delays of the data from the very region entering CATAC permit the use of alternative methods for the rapid evaluation of the seismic magnitude as the module FINDER from the Earthquake Early Warning software package provided by the Swiss Seismological Service to the countries of Central America. This method uses the high frequency spectrum of the recordings contrary to the very long period signals which are preferred normally for the evaluation of seismological parameters relevant for tsunami evaluation.

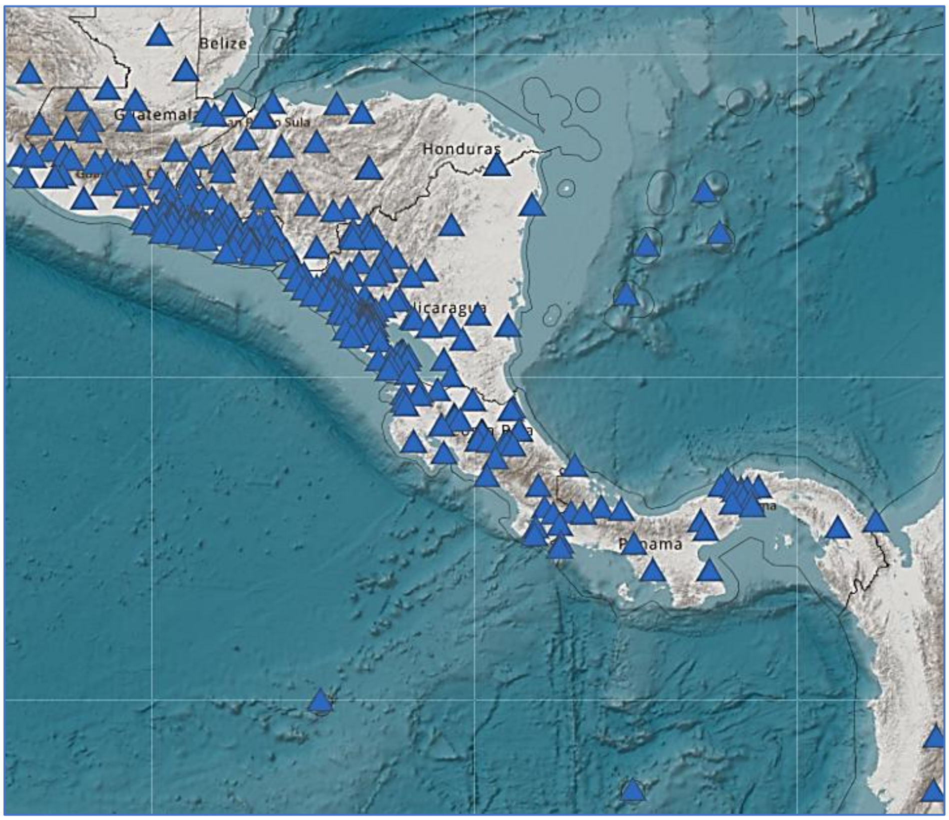

Figure 13. Location of seismic stations in Central American countries used by CATAC.

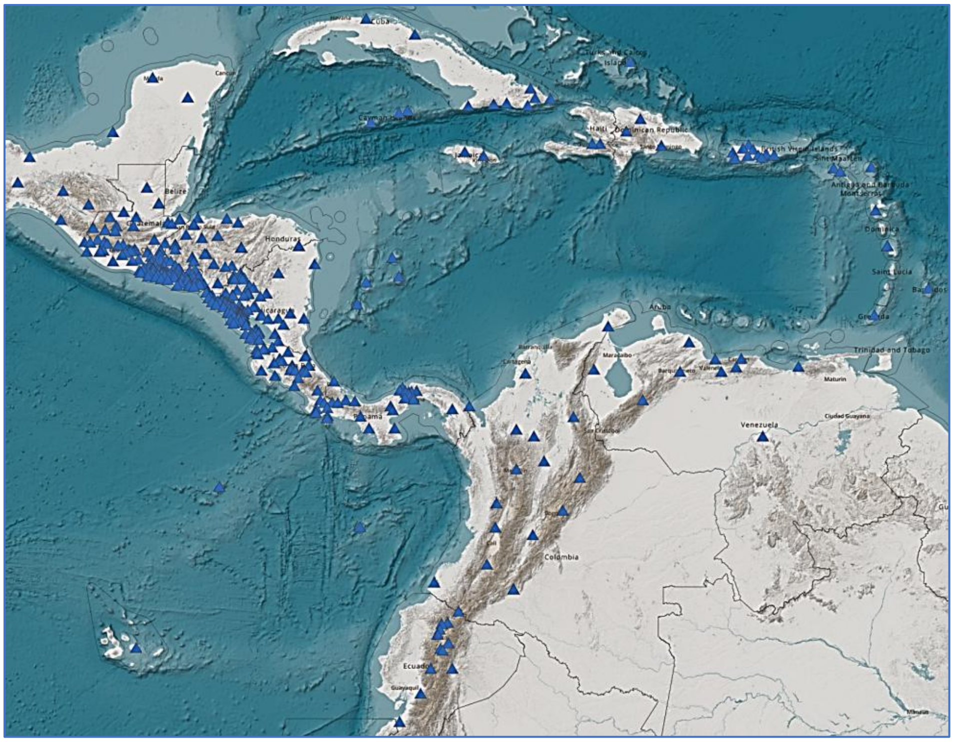

Figure 14. Location of seismic stations in the larger region used by CATAC.

Improvement of regional seismic networks The seismic networks in Nicaragua, El Salvador, and Guatemala were greatly densified in 2021 through the EWARNICA project with Switzerland, while improving the accuracy of earthquake locations. With the CATAC earthquake early warning methods, CATAC obtains a initial location and the magnitude of the earthquakes occurring in Central America within a few seconds after the start of the event. Also the calculations of the Moment Tensor and the Mw magnitude are accelerated.

CATAC´s global seismic monitoring CATAC maintains a special SeisComP system for global earthquake monitoring. This system provides locations and magnitudes of earthquakes with magnitudes above 5.5 worldwide. This system is useful when seismic waves emitted by these earthquakes are recorded in Central America. It also facilitates a awareness global of seismicity and zones close to the CATAC monitoring areas, such as South America and Eastern Caribbean. For big global earthquakes the CATAC SeisComP system also performs the calculation of the moment tensor and tsunami simulations.

Huge earthquakes are seldom in CATAC´s Area of Monitoring. CATAC is using its golbal monitoring facility to test its tsunami evaluation system and for the training of its personnel on the processing of strong earthquakes and tsunamis.

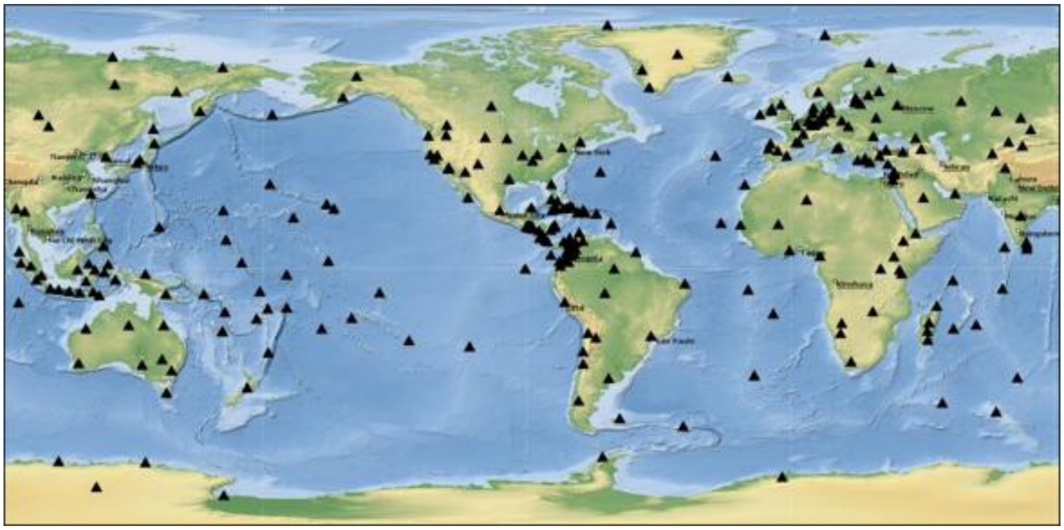

Figure 15. Seismic stations used by the CATAC global locator.

2.2.2 GPS/GNSS networks

In the last years methods were developed internationally to use displacement data obtained from GPS/GNSS for the characterization of large earthquakes. Magnitudes, moment tensors or event slip distributions can be obtained much faster than with the data from seismographs.

CATAC maintains in Nicaragua a total of 33 GPS/GNSS stations. Additionally there are available data from the stations of the Geodesy Department of INETER and the Cadaster Department. The data with a sampling frequency of 1 Hz from all stations are streamed with the BKG Caster software to CATAC to be converted into displacement and fed to the SeisComP system. CATAC is recently working to develop the capacity for the use of these real-time data for tsunami advisory. In the near future CATAC expects to receive also GPS/GNSS data streams from other Central American Geophysical Institutions.

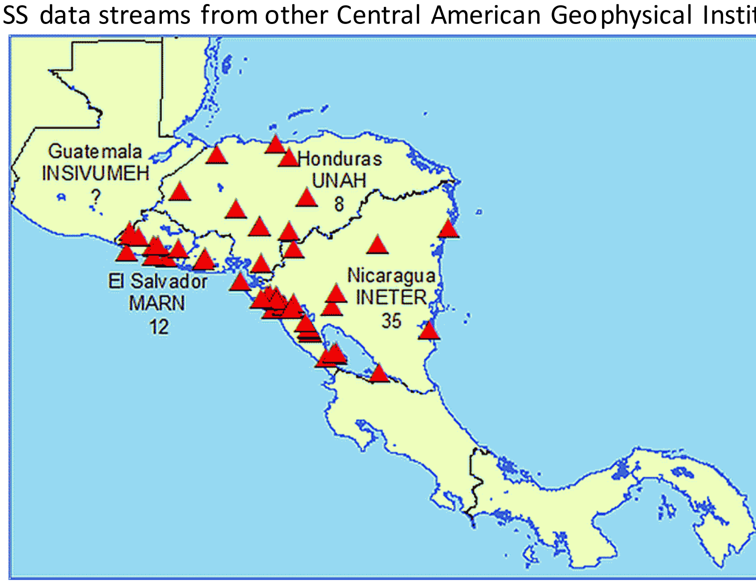

Figure 16. GPS/GNSS stations of CATAC and other geophysical institutions of Northern Central America

In Central America and the Caribbean there are many GPS/GNSS stations installed the data of which were exchanged freely during the project COCONET (with UNAVCO, now). INETER maintains since 2015 a regional mirror system of UNAVCO GPS stations in Central America and the Caribbean and expects to convert this system in a real time acquisition system for CATAC. maintained a server as a regional mirror for GPS/GNSS data from Central America and the Caribbean. CATAC pretends to make use of this experience and establish a real time download from these stations and use them (or a number of them for tsunami warning).

Figure 17. GPS/GNSS stations received at the Coconet mirror at INETER

2.2.3 Mareographic facilities

In case a tsunami is caused by an earthquake or any other event, its occurrence can be verified or measured using sea gauges located along the coast, deep water tsunami buoys, GPS/GNSS installed on large ships, GPS/GNSS or ocean radars located on the coast, or other appropriate methods.

CATAC´s SeisComP system receives data directly from INETER´s own sea gauges, or from foreign sea gauges via the COI/UNESCO sea level site (https://www.ioc-sealevelmonitoring.org/) operated by VLIZ. SeisComP´s TOAST module is used to visualize and process the data. Mareographic data are also received and visualized with TideTool (PTWC).

Mareographic stations in Nicaragua

INETER (both CATAC and Water Resources Department) has installed 6 mareographic stations on the Pacific Ocean coast of Nicaragua and 4 on the Caribbean coast. In some sites 2 stations are operating in parallel. In the last years the network has experienced strong impacts by hurricanes and ship accidents, instruments were lost and the network is in a process of restructuring.

A list and access to data of sea gauges in Nicaragua and the other countries of Central America can be obtained from http://catac.ineter.gob.ni/mareo.html.

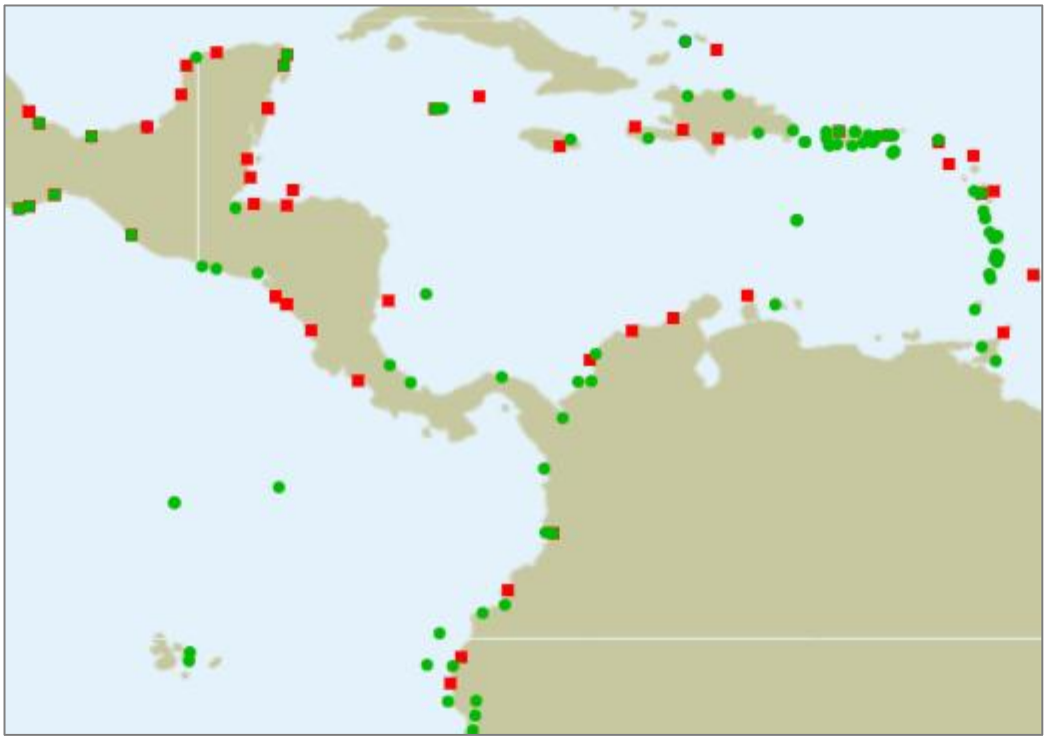

Figure 18. Sea level stations available to CATAC
(via www.ioc-sealevelmonitoring.org/map.php. Green squares - functioning stations; red squares - not operating stations at the moment of accessing the website. (page accessed on 28/08/2023)

New experimental buoys with GPS in the Pacific Ocean of Nicaragua

In March 2025, three buoys were installed in front of the Pacific coast of Nicaragua by the US Research vessel Atlantis in a project of CATAC with the University of Tampa, USA, OVSICORI (COSTA Rica) and other international scientific institutions. Another buoy was installed in front of Nicoya peninsula, Costa Rica. These 4 buoys transmit in real time estimates of both waves at ocean´s surface waves or tsunamis and the ocean bottom. There are possibilities to increase the number of these instruments. These data will permit to increase drastically the lead time of Earthquake and tsunami warning for Nicaragua.

Photo 7. Installation of a Buoy from the Research vessel

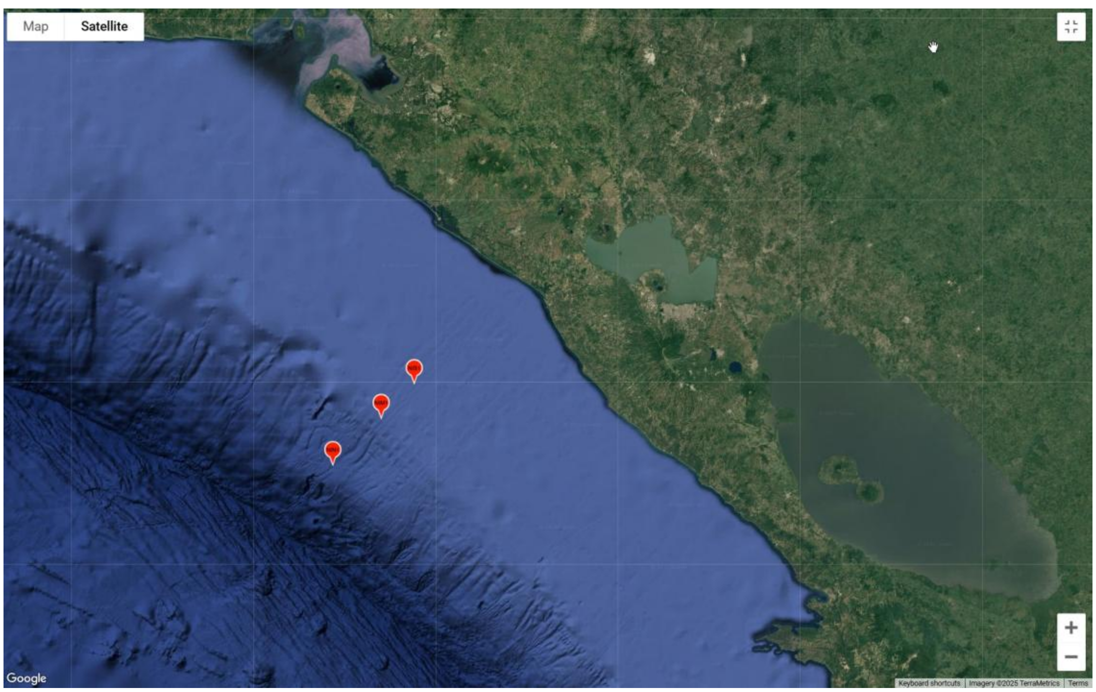

Figure 19. Location of the buoys in the economic maritime zone of Nicaragua

2.2.4 Volcano monitoring capacities for possible tsunami warning

CATAC uses its seismic and GPS stations for volcano monitoring in Nicaragua and cooperates with INETER´s Volcanology and Geology directorates which maintain other sensors as in the volcanic chain of Nicaragua for volcano and landslide monitoring and early warning.

2.3 Operational Tools and Procedures

CATAC uses the SeisComP software package (GFZ/Potsdam, GEMPA) with the PRO Extension for both automatic real-time and manual post-processing of seismic data and tsunami analysis. SeisComP was designed as a real-time data processing and fully automatic data acquisition tool, including quality control, event and location detection, as well as event alert dissemination. Also, additional functionalities were implemented to meet the requirements of 24/7 early warning centers. SeisComP is currently being developed by the Company GEMPA based in Potsdam, Germany.

2.3.1 Seismological Tsunami Source Characterization

Automatic and Interactive Moment Tensor Calculation The Moment Tensor is a physical description of the process of fault rupture that generates the displacement of the blocks under the seafloor that cause the tsunami and that emit the seismic waves that are recorded remotely and that allow the detection of the earthquake and the prediction of the tsunami before it reaches the coast. The determination of the Moment Tensor also makes it possible to determine the magnitude of the earthquake Mw with a higher precision than that allowed by simple methods that use the amplitude value of certain seismic waves to estimate the magnitude ML, Mb with certain formulas.

Automatic Moment Tensor Calculation After detecting and locating the earthquakes automatically the *SCAUTOMT* Module evaluates the seismic waveforms recorded at the different stations and compares them with the numerically simulated shapes with a certain model of the earthquake focal mechanism. By testing a large number of possibilities for hypocenter depth and varying the location and parameters of the fault it arrives at a result where the recorded data optimally matches the model. The SCAUTOMT module is configured to include near and far stations in the processing. Distant stations have the advantage that their records are not saturated, which would make the determination of the Moment Tensor impossible.

Interactive Moment Tensor Calculation The *SCMTV* module is used for the interactive calculation of the Moment Tensor. The operator can adapt the program to the specific situation of the event. By limiting the distance of the stations involved in the processing, the work can be accelerated.

The SCAUTOMT and *SCMTV* modules of SeisComP PRO use P-wave, S-wave, surface waveforms and W-waves to determine the Moment Tensor. CATAC previously used only broadband seismic station records for this process. However, broadband records located near the epicenter are often saturated by the high amplitudes of seismic waves and cannot be used for magnitude and Moment Tensor calculations. That is why CATAC also uses on a large scale the high quality accelerographic stations located in Central America for these purposes.

The W phase is a long-period phase that arrives before the S wave. Because of the fast group velocity of the W phase, most of the energy of the W phase is contained within a short time window after the arrival of the P wave. The amplitude of the long-period waves best represents the tsunami potential of an earthquake. By extracting the W phase from the vertical component of seismic waves, the Mw magnitude and source mechanism can be deduced for large earthquakes using the linear inversion algorithm. Previous studies (e.g. Argüello, 2016; Argüello et al, 2018)) show that W-phase inversion produces reliable and consistent CMT solutions that are necessary for numerical tsunami modeling. With the current CATAC-initiated enhanced seismic networks in Central America, the initial solution can be produced within 5-8 min after the occurrence of earthquakes of magnitude greater than 5.5 including data from stations up to 1000 km epicentral distance. Central America is a very narrow region and sometimes solution stability problems can occur due to insufficient azimuthal coverage. In this case it is possible to increase the distance of stations up to 1500 or 2000 km and repeat the calculation (Cabrera et al., 2021).

Exploitation of Earthquake Early Warning Results Since 2016, CATAC/Seismology has been developing together with the Swiss Seismological Service (SED) at the ETH Zurich University an earthquake early warning system (Earthquake Early Warning - EEW) for Nicaragua. This project was extended from 2020 also to other Central American countries and largely supported in the development of CATAC (Massin et al, 2018).

A primary objective for EEW is the immediate estimation of the location and magnitude of the seismic event within seconds after or even during the rupture of the earthquake fault. The fast magnitude estimation algorithms created for EEW can be useful for Tsunami Warning. Also, the fast location of the seismic event provided by EEW is important for the tsunami topic, especially in those coastal regions where tsunamis may arrive a few minutes after the crustal rupture process ends.

Tsunami mitigation efforts can be seriously affected by the seismic impact of the earthquake that generated the waves. NTWC and Civil Protection institutions should have an estimate of the level of impact or destruction as soon as possible to adapt mitigation measures (e.g., evacuation) accordingly. The ATT requires very rapid methods to alert large numbers of people of the impending impact by an earthquake and the same methods serve the tsunami warning.

CATAC was requested by the ICG/Caribe-EWS in 2024 to make use of these capacities and is in the process of implementing EEW methods to accelerate tsunami warning in Central America and promote its application.

Earthquake Impact Scenarios, Shakemaps As part of the Earthquake Early Warning project with SED/ETH, procedures for generating and distributing Shakemaps in near real-time for Nicaragua and Central America were implemented in March 2017 (Cauzzi et al., 2018).

In tsunami response planning, it is crucial to consider the seismic impact near the source, as these effects can hinder evacuation, contribute to wave-borne debris, and amplify tsunami impacts. To assess earthquake impact, the USGS developed ShakeMap and PAGER (Prompt Assessment of Global Earthquakes for Response). ShakeMap provides visualizations of ground shaking levels, analyzing earthquake magnitude, distance from the epicenter, regional geology, and seismic wave propagation. PAGER then estimates the population exposed, potential fatalities, and economic losses based on ShakeMap data.

CATAC generates Shakemaps within minutes of an earthquake and makes them available via its website.

In 2025, CATAC plans to acquire licenses from GEMPA for the use of SeisComP modules which permit earthquake impact scenario modeling and Shakemap calculations.

2.2.3 Tsunami Forecasting

Tsunami Forecast Models CATAC uses for quantitative tsunami warnings a real-time numerical simulation technique which is implemented in the SeisComP PRO Module TOAST elaborated by GEMPA.

Real-time tsunami forecast model SEISCOMP PRO, the seismological software package used at CATAC for earthquake detection, location and magnitude determination has a real-time tsunami forecast model based on the *TOAST* module (Tsunami Observation and Simulation Terminal; GEMPA, https://www.gempa.de/products/toast/). TOAST is *a* tsunami simulation and verification software for rapid hazard assessment. The results can be verified by oceanographic sensors such as tide gauges or buoys. *TOAST* is the complement to SeisComP3 for the implementation of a fully functional tsunami warning system. In addition to this in-flight simulation the *TOAST* interface for flexible simulation also allows the integration of existing pre-calculated scenario databases.

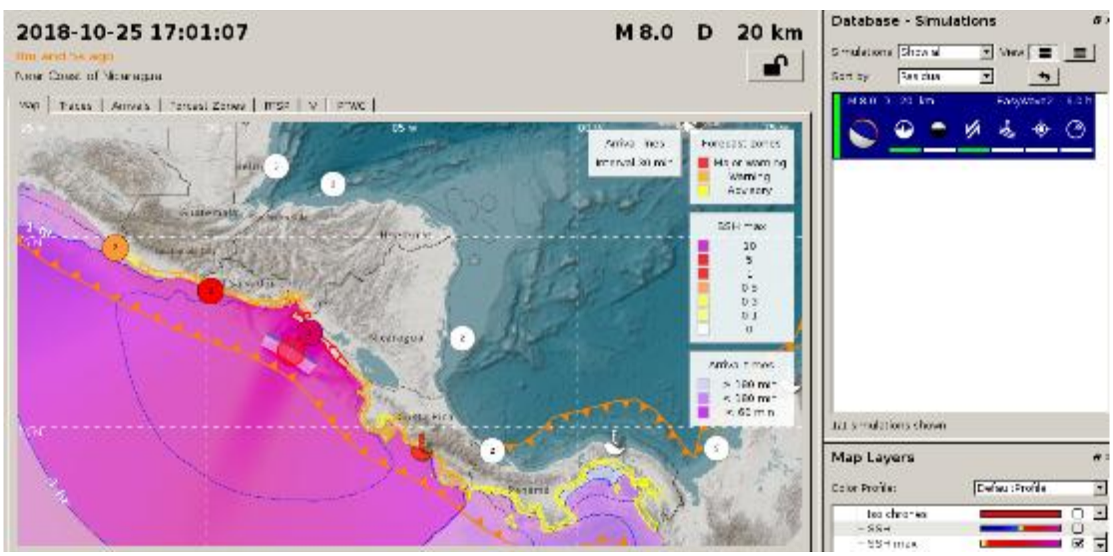

Figure 20. TOAST simulation of tsunami propagation of a magnitude 8.0 event off the Pacific coast of Nicaragua

TOAST module workflow TOAST connects to the SeisComP3 system and listens for internal system messages with parameters of the incoming earthquake. In case a hypocenter and magnitude arrive, TOAST uses a formula from Wells & Coppersmith (1984) to generate the rupture size based on the magnitude. By default, the rupture area is centered around the epicenter, and strike and dip information are derived from preconfigured fault information. Once the rupture area is generated, the simulation plug-ins are activated.

EasyWave application for tsunami simulation By default, TOAST uses the EasyWave program (https://gitext.gfz-potsdam.de/id2/geoperil/easyWave) an application used to numerically simulate tsunami generation and propagation in the context of early warning (Babeyko, 2012). It makes use of Graphics Processing Units (GPU) to considerably speed up the calculations. The rupture area can be placed at several preconfigured positions with respect to the hypocenter and simulations for several positions can be computed on the fly in parallel. As the earthquake information is changing over time, with each relevant update new simulations are automatically triggered. But rupture areas can also be generated manually and simulations can be started using these.

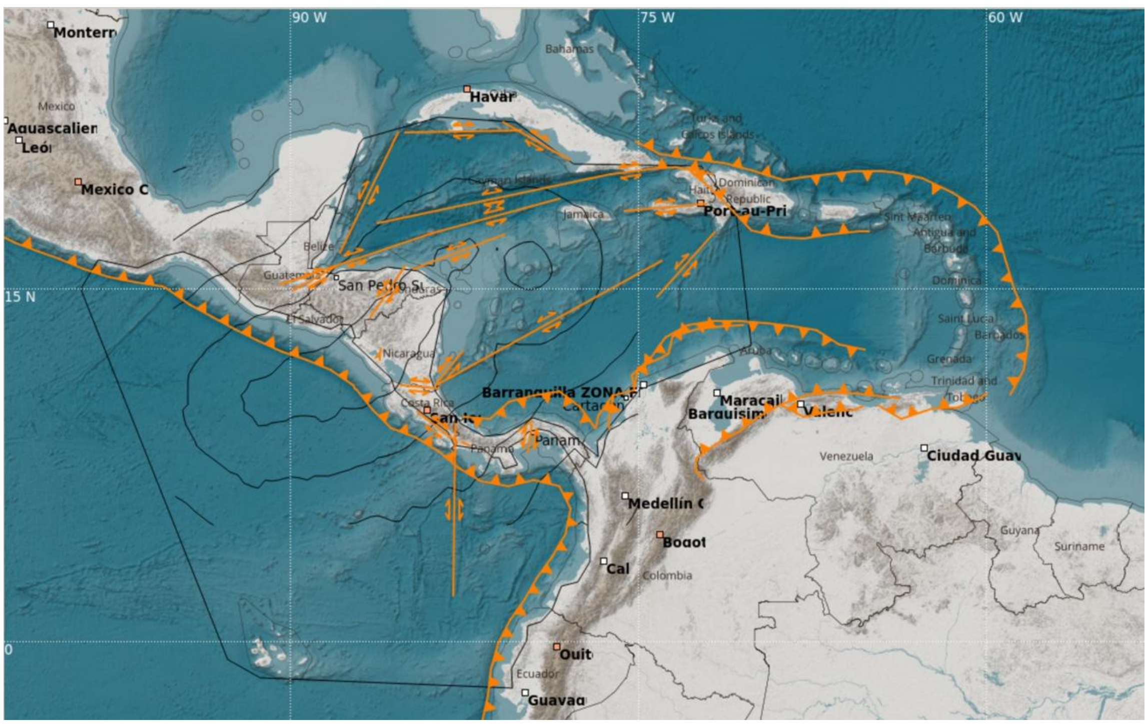

Figure 21. Plate boundaries with subduction process (yellow line with triangles) and other main faults (yellow line) in the CATAC monitoring area. When CMT is not yet known, TOAST uses a database of parameters of these faults as input for initial tsunami simulation

TOAST provides different perspectives showing the simulation results. The following features are shown:
- Simulated as a function of time Sea Surface Height
- Simulated sea surface height
- Simulated isochrones
- Simulated tsunami travel times

- Estimated tsunami arrivals
- Tsunami coastal wave height estimation.
- Observations of tsunami arrival through manual picking
- Observations of tsunami wave heights/periods by manual picking
- Points of interest and oceanographic sensors
- Failure information
- Rupture area
- Seismic parameters
- Simulation progress
- Simulation quality
- Newsletter

To verify the simulation results, *TOAST* provides a manual tsunami onset selector, which allows selection of arrivals, amplitudes and periods based on real-time sea gauge observations. The observed information is then used to calculate the quality of a scenario that represents the agreement between the simulated and observed values.

For example, the quality of oceanographic sensors is indicated by the color of the tide gauge symbol in the simulation widget. The simulation widget displays these quality parameters not only for tide gauge data, but also for epicenter location, depth, magnitude, comparison with preconfigured rupture mechanisms, and existing moment tensors. The quality information may change over time as it compares the simulation information with the actual information.

Interpretation of model results The uncertainties associated with the tsunami propagation scenario database and numerical models come from the CMT solution, interpolation between neighboring scenarios, numerical modeling of the propagation, as well as Green's law extrapolation. Each uncertainty can result in large errors. For example, numerical forecasts can easily vary by a factor of two due to uncertainties in earthquake magnitude, depth and assumed mechanism; Green's Law is very sensitive to local topography and bathymetry, and the coastal amplitude could be over or underestimated by a factor of 2-3 depending on coastal features; the effect of wave dispersion is significant for distant tsunami propagation.

Therefore, to understand the numerical forecasts is very important for national receivers to correctly recognize tsunami hazards. Basically, CATAC interprets the numerical results by classifying them into several categories. In CATAC's Tsunami Advisory Products, the coastal amplitude forecast at each forecast point is classified into four threat levels of <0.3 m; 0.3-1 m, 1-3 m and above 3 m, which are illustrated with different colors along the coasts. The practice is the same as that of the PTWC New Enhanced Products.

2.2.4 Decision Support

The TOAST module of SeisComP provides graphical, tabular and text information for the decision support to be used by the 2r4x7 watch standers.

2.2.5 Product Creation and Dissemination

CATAC tsunami advisory products are issued when an earthquake with moment magnitude 6.5 or greater is detected in one of the CATAC Monitoring Areas.

Text bulletin The Text bulletin is available to the public and NTWCs. Typically, the CATAC text product contains earthquake parameters, tsunami genic potential, tsunami amplitude and ETA forecasts for Coastal Forecast Points, tsunami observations and recommended actions. As the CATAC products are destinated for the Central American countries the messages are in Spanish language. English versions are sent only to the PTWC, NWPTAC, and other interested institutions in the IOC/UNESCO domain.

Coastal Forecast Points The estimated tsunami amplitudes and estimated times of arrival (ETA) are provided for coastal forecast points in the CATAC region. These coastal forecast points are points chosen by CATAC Member States. They correspond to coastal cities and tide gauge station sites. In the tsunami threat message, all forecast points with maximum amplitude greater than 0.3 meters are listed in groups according to Member States. Tsunami amplitude estimates are grouped into four clusters of <0.3 m; 0.3 to less than 1 m; 1 to 3 m; and greater than 3 m.

Tsunami Energy Map The tsunami energy map gives the distribution of the maximum tsunami amplitude in the CATAC region color coded. The direction of the tsunami energy beam and the threatened areas can be easily identified by the different color. The tsunami travel time (TTT) contours are shown in light gray lines and are superimposed on the tsunami energy map.

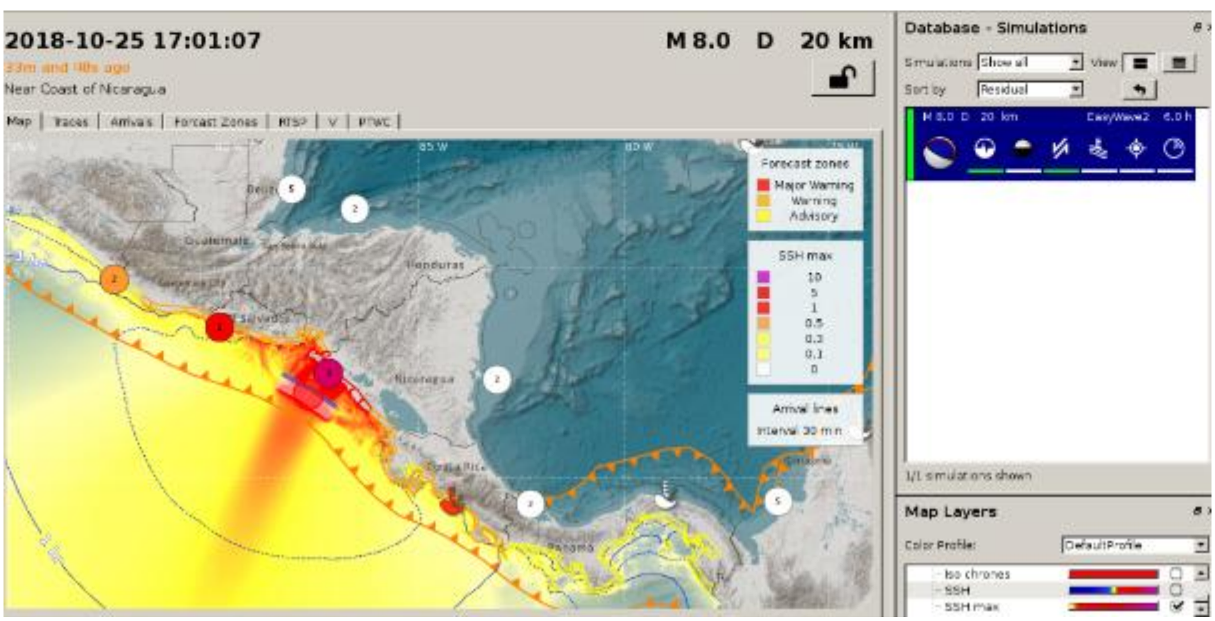

Figure 22. Tsunami energy radiance of a simulated event of magnitude 8.0 off the Coast of Nicaragua, created with TOAST.

Coastal Prediction Map The coastal forecast map provides a detailed view of the tsunami threat along the coasts of the CATAC region. It divides the CATAC coastlines into a series of modeling output sites. Each site is colored according to the tsunami amplitude corresponding to the model grid points closest to the site. The tsunami energy map is also overlaid in gray shading style with illuminated effect and in addition there are TTT contour lines placed.

2.2.5 Dissemination and Services

Computer Base Messages are generated with *GDS, QuakeLink and GIS*, which are SeisComP3 modules that collect event information and disseminate template-based messages through various communication channels such as SMS, email, fax and web. Using plug-in technology, they import and filter seismic information from different sources before dissemination. *GDS, QuakeLink and GIS* complement SeisComP and *TOAST* functionalities in the area of notification and alert dissemination.

- Text messages and graphic products including tsunami energy maps, coastal forecast maps are sent to NTWC/TWFPs in Central America via email, SMS, Whatsapp and the password protected CATAC website.
- In Nicaragua short text messages are disseminated through the EWBS system of digital TV to many institutions and the general public, starting December 2021. In the other countries of the region, TWFPs could follow this example.
- The earthquake Early Warning Messages are disseminated also with an Apple / Android app.
- The text messages are posted on CATAC's website for the general public, together with graphic material on the earthquake which generated the tsunami.

2.2.6 Timeline

The timeline of the combined automatic and manual processing is displayed in the following table. The times are only estimates:
(Abbreviations **:** SeisComP = SC, EEWS= Earthquake Early WarningSystem, ASS= AlertSeismicScript, TOAST= Tsunami Observation and Simulation Terminal, SCMT-SeisComP Moment Tensor Module, GDS= Gempa Dissemination Server, Graphical products: Maps of tsunami Energy Emission max SSH and Map of Coastal stripes Max SSH)

Table 3. Timeline

Time/ minutes	**Occurrence / Actions**
00	An earthquake rupture initiated in the CATAC Monitoring Areas. P-and S-waves are leaving constantly from the rupture. (The rupture might take up to 3 minutes in total. So, first seismic and tsunami products might be sent out before the rupture finishes).
0-0.3	**SC detects P waves with at minimum 4 seismic stations**, tries to compute a reliable location within 4 seconds and the initial magnitude only from P-waves
0.1-0.3	**EEWS generates an EEW message and sends it automatically** to recipients in Nicaragua - only if the magnitude is bigger than 4 and the epicenter lies in Central America.

0.5-2	**SC detects P and S waves at 15 or more stations**, hypocenter is located and computes a more reliable magnitude from S waves – **ASS sends automatically an info** with only seismic parameters to the recipients, if magnitude is 5 or bigger. For magnitudes below 6.5 saying "no tsunami is possible".
0.5-2	TOAST automatically does tsunami simulations based on initial earthquake parameters adding rupture parameters according SC fault data base. Propagation is limited to 3h to reduce GPU processing to less than 10s.
2	**Operators revise automatic location and magnitude** and confirm or produce corrected manual solution.
3	**TOAST proposes the first CATAC tsunami text product** based on information from real-time simulation along with updated preliminary earthquake parameters. -Operator revises predicted impact hazard maps for coastal stripes Operator -accepts the text - or – selects another (newer) or "higher hazard" estimate, judging from hazard map of coastal stripes
	Another CATAC text product may be issued this way if the earthquake parameters change considerably in the first minutes.
5	**Operators divide work: one dedicates to SCMT, the other works with TOAST**
8	**TOAST presents automatic or manual CMT solutions of SCMT** which may be revised by operator TOAST map and lists; The simulation in real time is recalculated again using CMT results and 3 hours propagation time
10	**TOAST produces the second CATAC text product and graphical products** based on real-time numerical simulation using CMT.
10	An initial text product from PTWC CATAC might arrive at CATAC and is compared with CATAC´s products. Eventual corrections are made. Possible interaction CATAC-PTWC.
15	Operator does other real time tsunami simulation with 4 hours tsunami propagation time; text and graphical products are **sent to the recipients with the third message.**
20	A real time tsunami simulation is carried out again with 8 hours tsunami propagation time and the text and graphical products are **sent to the recipients with the fourth message**
30	First tsunami arrivals are detected at sea gauges and informed to the recipients with a text message. Possibly a reinterpretation has to be carried out and a new product is to be sent to the **recipients with the fifth message.**
60	More tsunami arrivals are detected at sea gauges and informed to the recipients. Possibly a reinterpretation has to be carried out and product to be sent to the recipients
120 or more	Final product with text and graphical products with a possible cancellation of the tsunami threat with **the final message**

3. Products

3.1 Product Types and Criteria

3.1.1 Informational

CATAC issues seismological products for earthquakes above magnitude 5 that have occurred in the Area of Monitoring. In this case only a short tsunami note is given that this earthquake is too small to generate a tsunami. About 50 earthquakes with these characteristics occur within one year with these characteristics. These messages have beside the information also the function to test the messaging facilities of CATAC and to remember the existence of CATAC in between the occurrence of strong earthquakes.

CATAC issues products for large earthquakes with magnitudes between magnitude 6.5 and 7.0 that have occurred in the Area of Monitoring but that present no tsunami threat to the Area of Service. The reasons for excluding the possibility of a tsunami are given. For these earthquakes a numerical tsunami simulation is carried out and an estimate of the maximum wave heights at the Central American coasts are obtained but remain below 30 centimeters for all coastal areas. The values might be discussed with the NTWC´s by telephone of chat. These events might occur three times per year in the Area of Monitoring.

In some situations, an informational statement is sent out – for example in the case of a very distant source or when the tsunami threat to the Area of Service is still under evaluation. The latter may occur in the case of the occurrence of a slow earthquake where the initial magnitude determination is below 6 but later shows an increasing tendency.

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3.1.2 Threat .

At the Twenty-fifth session of the ICG/PTWS (ICG/PTWS-XXV/3 rev.) held from 11 to 13 September 2013, all Member States agreed on a changeover to the PTWC New enhanced Products suite since 1 October 2014. As each Member State is sovereign and thus responsible for taking actions to ensure the safety of its own population, the PTWC New Enhanced Products no longer use levels of alert (i.e., watch and warning) to define the tsunami bulletins, and instead provide levels of threat based on numerical modelling. The levels of threat now are provided as expected maximum tsunami wave amplitudes relative to the tide within four categories which are: (i) less than 0.3 metre, (ii) 0.3 to less than 1 metre, (iii) 1 m to 3 metres, and (iv) greater than 3 metres.

The CATAC Tsunami Advisory Products stick to practice of PTWC, NWPTAC and SCSTAC to provide quantitative tsunami threat to recipients, rather than warning levels that are more meaningful for domestic warnings. According to numerical studies in the CATAC region, tsunamis may hit within few minutes, thus there are not much time left for emergency response. Basically, CATAC will send out the initial bulletin as soon as possible mainly based on the preliminary earthquake parameters like location, magnitude and focal depth. Whether a Member State will be put into 'threat area' depends on the relatively conservative output of initial numerical simulations based on the initial earthquake parameters.

CATAC now uses W-phase Centroid Moment Tensor analysis SCMT of SeisComP, which is typically available about 5-20 minutes after the earthquake, to trigger the numerical modelling. It´s important that the SCMT can yield a more accurate initial condition which is critical to tsunami modelling result. While SCMT analysis is appropriate for more distant or regional tsunami sources, for local tsunamis in Central America it might take too much time to provide the quantitative forecasts using this technique. Therefore, tsunami automatic simulation based on the preliminary earthquake parameters and assumption of the fault parameters from SeisComP fault data base, in combination with rapid tsunami models, will be adopted to evaluate coastal threat levels quantitatively in the subsequent bulletin that comes up 3-5 minutes after the first one. After that, the supplementary bulletins may be issued if major earthquake magnitude revision occurs. CATAC will also run the high-resolution regional models when SCMT analysis is available, however the main purpose is to update and validate the preceding forecasting results.

Bulletin type		**Criteria**	**Content**	**Timeline**
Tsunami Information	Only one bulletin	Magnitude of 6.0-6.4; or on land; or depth≥100km	EQ parameters and statement of 'No tsunami threat'	5-10 min
	Only one bulletin unless minor waves observed and should be reported	Magnitude of 6.5-7.0	EQ parameters and statement of 'No tsunami threat'	5-10 min
Tsunami Threat Message	Bulletin with quantitative forecast	≥7.0 and shallow under water earthquake	EQ parameters and quantitative forecasts on threat level and Estimated Time of Arrival (ETA)	8-15 min
	Supplementary with observations		EQ parameters, quantitative forecast and tidal gauge observations	If revision on EQ & tsunami forecasts, or observation available
	Final bulletin		Statement of 'No tsunami confirmed or threat passed'	hazardous waves has passed or no significant tsunami observations

Table 4. Criteria adopted by SCSTAC

In Tsunami Information or Tsunami Threat Message, the tsunamigenic potential is provided based on preliminary earthquake parameters as follows:

Magnitude (Mw)	**Tsunami Potential Description**
$6.0 \leq M_w \leq 7.0$	There is no tsunami threat from this earthquake
$7.1 \leq M_w \leq 7.5$	Possibility of a destructive local tsunami confined to 100-300 km of the epicentre
$M_w \geq 7.6$	Possibility of a destructive basin-wide tsunami

Table 5. Tsunamigenic potential adopted by SCSTAC

As the numerical tsunami simulation with the new Graphical Processing Units GPU are now about 20 times faster than in the initial phase of CATAC it is now possible to repeat the simulation with different duration of the tsunami propagation and estimate the wave height in the coastal areas after more than 8 hours. Experience has shown that in case of very large earthquakes in Southern Mexico the maximum tsunami reached the Pacific coasts of Central America around 10 hour after the earthquake.

3.2 Product Content

3.2.1 Text Products

Basic considerations The messages from PTWC are sent in English and use wording which seem to have some legal background to be considered in the United States. Original discussions in Central America about CATAC products highlighted the interest to receive shorter and concise messages in Spanish language without much technical and legal wordings. This is especially important for users in the civil protection agencies as their personnel frequently lacks sufficient knowledge of the English language or of scientific terms. Thus, the text messages of CATAC are very short and concentrate on the presentation of the general threat estimate or on the threat levels for the different coastal stripes of the countries.

Interpretation of the model results The uncertainties associated with the tsunami propagation scenario database and numerical models come from the SCMT solution, the interpolation among neighbouring scenarios, numerical modelling of propagation, as well as Green's Law Scaling. Each uncertainty could result in large errors. For example, numerical forecast results can vary easily by a factor of two because of uncertainties in the earthquake magnitude, depth and assumed mechanism; Green's Law is very sensitive to local topography and bathymetry, coastal amplitude could be over- or under-estimated by a factor of 2-3 depending on coastal features; wave dispersion effect is non-negligible for distant propagation of tsunami wave.

3.3 Graphical Products

How to comprehend numerical forecasts is very important for national recipients to recognize the tsunami threats correctly. Basically, the other tsunami service providers in the Pacific like PTWC, NWPTAC, SCSTACC interpret the numerical results by classifying them into several categories. In the PTWC New Enhanced Products, the coastal amplitude forecast at each forecast point is categorized into four threat levels of <0.3m; 0.3-1m, 1-3 m and above 3m, which are illustrated by different colors along the coastlines.

4. Dissemination

4.1 Methodologies

4.1.1 Dissemination of Products

Nicaragua In Nicaragua, sirens are the main system to disseminate the warnings of CATAC to the coastal population. Since 1915, there are 60 sirens installed in the communities at the Pacific coast. Twenty additional sirens were installed, in 2022, in communities along the Caribbean coast that means there are now in total 80 sirens installed on both coasts. Most of the coastal population is in reach of the acoustic signals emitted from this system as typical siren sound or speech "Alerta de tsunami!". Thus, the vast majority of the entire population under tsunami danger can receive CATAC warnings by this means. The sirens are controlled by the Civil Defense organization of the Nicaraguan Army via a digital VHF radio system. After receiving a warning message, they activate by pressing a single switch or using a computer all sirens of a coast or part of them. While the system was installed for tsunamis warning the sirens can also be used for other emergencies. Each siren can also be activated locally if necessary. The sirens a completely independent from commercial electrical power as each device has a solar panel and a battery. The siren system is maintained by the Civil Defense of Nicaragua.

Photo 8. Maintenance of a tsunami siren

Taken from https://www.canal4.com.ni/defensa-civil-da-mantenimiento-a-sistema-de-sirenas-de-alerta-temprana/

Figure 23. Location of sirens on the Pacific and Caribbean coasts of Nicaragua.

Sirens in other Central American countries The installation of sirens has also begun in the other Central American countries but up to the moment no other country has reached the completeness of the siren system as in Nicaragua.

Development and test of a cellphone app for tsunami warning CATAC has developed for Android cellphones a real-time application for tsunami warning and evacuation route information in the Pacific coastal areas of Nicaragua. The message of CATAC is transmitted to cellphones and the application presents the position of the user according its GPS in a map where the coastal strip is coded according the tsunami hazard, together with routes to safe places. The app is not yet in regular use.

Early Warning Broadcasting System of the digital TV CATAC participates in a massive experiment on the use Early Warning Broadcasting System of the digital TV for the transmission of warning messages to the public which is going on in Nicaragua since 2022.

Direct Computer-Computer messaging CATAC uses software modules of SeisComP to communicate its products to institutional users in Nicaragua. A SeisComP SCESV module is run on small computers (eg. Raspberry Pi) to present real time graphs of the earthquake processing. That way Nicaragua for many years in the Monitoring and Situation rooms of SINAPRED and Defensa Civil.

Delivery of products to the costumers in other Central American countries
Email - CATAC´s texts and graphical products are sent to its regional customers using email. The messages are sent out using INETER´s mailserver. If there is found a problem with this server, the sending out is switched to the use of the Google mailserver GMAIL.

Whatsapp – CATAC sends out messages manually to existing Whatsapp groups. The message is send automatically using an API to a limited number of recipients (the official Contact list from COI/UNESCO).

Telegram –Telegram is used, since 2021, for sending out CATACs messages automatically to users in Nicaragua. Since 2025, CATAC also the capacity to send these messages to regional users in Central America.

Website - The seismic and tsunami products are published in CATAC´s website http://catac.ineter.gob.ni.

Direct Computer-Computer messaging CATAC uses software modules of SeisComP to communicate its products to institutional users in Central America as described above for Nicaragua. To the seismic observatories in Central America, often the NTWC´s, is offered to import the CATAC numerical solutions (that means earthquake locations, magnitudes, phase pickings, time residuals, etc.) directly via Internet in their own SeisComP system. That way they can check them or merge the results immediately with their own results or even adopt CATAC´s results and use them for their needs. On the other way CATAC can also import their solutions. This is completely automatic and an extremely fast way to exchange results. The comparison of the results of other observatories may diminish the possibility of gross interpretation errors.

4.1.2 Customer Decision Support

As in the past, CATAC staff will reach out to customers, i.e. seismological or tsunami observatories and civil protection agencies, during events to ensure they are aware of a tsunami situation and ensure they have received any TSP products issued. CATAC also provides additional information to help with customer decision-making Voice Calls using ordinary or cell phones or Whatsapp or Whatapp chats.

CATAC maintains a contact list of their customers which can be used to call them in case of an emergency.

Non routine phone calls and chats were in the past ad-hoc and voluntary depending on staff availability, mainly from CATAC´s director but CATAC has started to transmit its threat messages via Whatsapp.

Voice Calls Calls using ordinary or cell phones or Whatsapp with official contacts of the IOC/UNESCO list These calls are done normally by one of the leaders of CATAC but any 24x7 operator is qualified to realize these calls.

Chats via Whatsapp The most common social network for chatting in Central America is Whatsapp. CATAC stared using it in 2025 with official contacts or relevant individuals well known by the CATAC**.** As CATAC has a close cooperation with the institutions in Central America there is also the possibility to communicate with key persons who are not in the official lists.

Whatsapp Chats with groups of users Frequently, CATAC text messages and graphical products are sent to regional or national Whatasapp user groups, as for instance "Tsunami Centroamérica", Tsunamis Centroamericanos, which comprise personal of NTWCs in the region and "Comité de Tsunami Panama" integrating personal related to tsunami warning and mitigation in Panama.

4.2 Communication Testing

In the case of CATAC special procedures to test the delivery of its messages to the customers seem not to be necessary as is explained in the following:

Supervision of seismic data streams CATAC is receiving continuously data streams from most of the NTWC´s in Central America, the exception is only SINAMOT in Costa Rica which does no has own seismic stations. When these streams are interrupted CATAC knows that also the messaging with the NTWC´s might have suffered and will take measures with the corresponding institution to solve the problem.

Supervision of seismic information messages CATAC interchanges, several times per day, email messages about small earthquakes with the NTWC´s as seismological observatories. As soon as CATAC receives notes from the email client that certain messages could not be delivered, the institution is contacted by other means to investigate and solve the problem.

4.3 Conducting Regional Tsunami Exercises

In the experimental phase, CATAC conducted two exercises for Central American countries:

a) Mega earthquake in the subduction zone between Guatemala, El Salvador and Nicaragua.

Date of exercise 1: 08/19/2019

Earthquake parameters:

Magnitude 8.6, with a complex source that would generate a maximum possible tsunami in Central America of more than 20 m in height.

The modeling was done with SeisComP TOAST, in "real time".

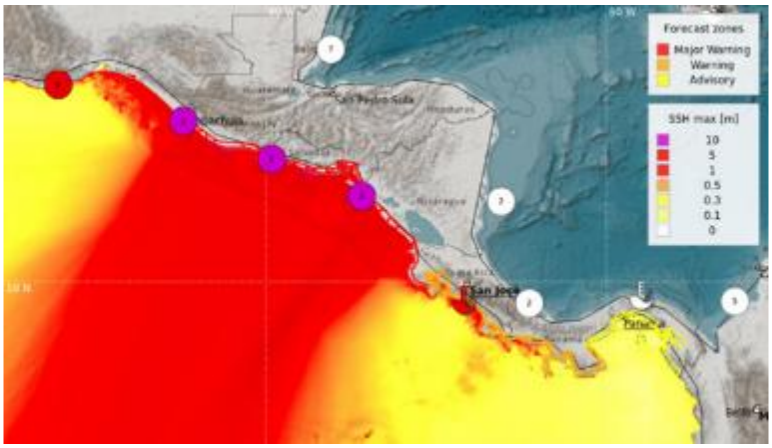

Figure 24. Tsunami map of exercise with M8.6 EQ.

b) Slow earthquake of magnitude 7.6 off the Gulf of Fonseca

Exercise date 2: 11/11/2020

Earthquake parameters: M 7.6, slow earthquake and tsunami impacting El Salvador, Honduras and Nicaragua, Honduras, Nicaragua)

Modeling with: SeisComP TOAST

This exercise was conducted under COVID-2019 conditions.

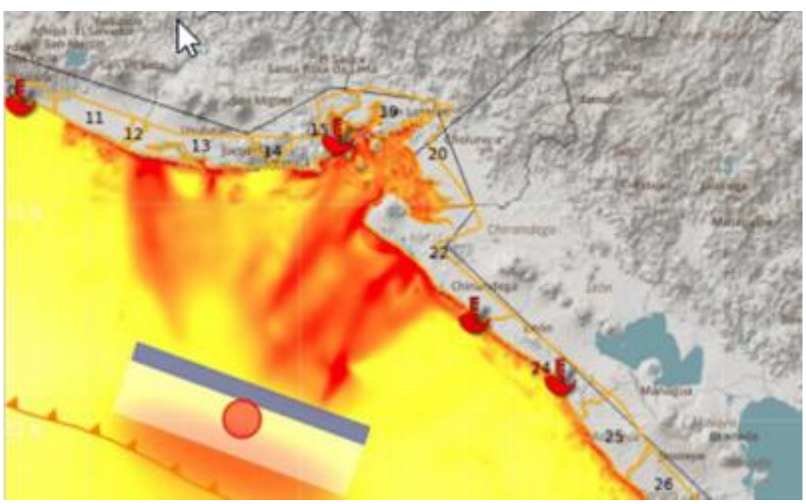

Figure 25. Tsunami map of exercise 2.

Other planned exercises were cancelled due to the Covid 2019 crisis..

4.3 Capacitation

4.3.1 Capacitation of CATAC personnel

During the development of CATAC the following capacitation measures were carried out:

One-year Seismology Course at UNAN University In 2015-2016 CATAC´s personnel who previously had no degree in Earth sciences (but in other fields as engineering, IT, Computer science, etc.) were trained on seismology at the UNAN university in Managua .

Master´s degree on Earthquake and Tsunami at GRIPS in Japan Seven CATAC personnel have obtained their master´s degree in Japan on Earthquake and Tsunami sciences

Master´s degree on Disaster Prevention at UNAN in Managua So far, three of CATAC´s personnel have obtained a Master´s degree on Disaster prevention, including seismology, at UNAN in Managua.

Courses about SeisComP All CATAC personnel received several courses on the processing of Earthquakes and Tsunami with the SeisComP software system within the CATAC project 2016-2019 with JICA on the enforcement of CATAC. Also the Project with the Swiss technical cooperation on Earthquake Early Warning carried out capacitation measures on SeisComP.

Capacitation for the 24x7 duty New CATAC personnel who is pretended to work as watch standers in the 24x7 shifts has to undergo a personal training which is run by already experienced watch standers. They participate around half a year in the daytime shifts

4.3.2 Capacitation of personnel from user institutions in Central América

During the reinforcement of CATAC in 2016-2019 several efforts went on to capacitate CATAC´s future customers i.e. the scientific institutions or NTWC and the civil protection agencies or TWFP. Especially two UNESCO projects on the elaboration of Standard Operation Procedures SOP in the countries of Central America are to be mentioned in which participated both the NTWC as well the TWFP. But, as CATAC was not yet officially established as a Tsunami Service Provider it was not included in the SOPs but only the PTWC remained as the source of tsunami information.

Unfortunately, the capacitation process was interrupted due to the pandemic COVID-2019. While CATAC continued operating normally most related institutions suffered heavy restrictions of their activities. It was impossible to visit the countries and institutions.

In March-June 2023, CATAC with the help of JICA and CEPREDENAC carried out 17 webinars of 2 hours duration, to discuss in each of the 6 countries of Central America, Belize and Dominican Republic with its customers about CATAC´s procedures and products. The topics presented and discussed were Tsunami Hazard country specific; Minimum dangerous tsunami height; Zones with small impact times; CATAC procedures; Tsunami simulation; Warning products; Warning messages; Warning methods (social networks); Recipients of messages; Country protocols; Proposals.

The institutions were asked about the established SOPs in the different countries and institutions, and it was found that - with exception of Nicaragua - CATAC, though it is known and its messages are received, is still not considered in the official procedures.

Thus, CATAC, JICA and CEPREDENAC developed the idea of a capacitation effort to change this situation. A project proposal was elaborated to be funded by JICA and to be executed from 2023 till 2026. It foresees the execution of a virtual meeting of

On September 1st, 2023, JICA published a call for the "Third Country Course for the Strengthening in the use of the Earthquake and Tsunami Warning products of the Central American Tsunami Advisory Center (CATAC)", to be held in two phases. The first phase in virtual mode, from November 13 to 17, 2023 and the second phase in face-to-face mode, from November 20 to 24, 2023 in Nicaragua. The objective of this course is to train key personnel on CATAC methods and products for earthquake and tsunami warning and their proper application by civil protection institutions in Central American countries, as well as to promote the exchange of experiences and knowledge among participants. In this regard, the excellent efforts of CEPREDENAC were requested in order to share the information of the course to the civil protection institutions of the Central American region. An invitation was extended for the participation of a CEPREDENAC official during both phases and two representatives of this organization participated in the course. In addition, on November 20, 2023, an inauguration ceremony was be held with international participants and Nicaraguan authorities.

This course was repeated in November 2024 and will be run again in November 2025. Additionally, visits of CATAC personnel to all institutions which receive CATAC products in the Central American countries (besides Nicaragua) were carried out in 2023 and 2024 (Guatemala, El Salvador, Honduras, Costa Rica and Panama). The Central American Disaster Prevention Center (CEPREDENAC) was also visited in both years to discuss the use of CATAC products by this entity. CEPREDENAC requested to draw attention to the countries of Belize and Dominican Republic which are members of SICA and CEPREDENAC but are not included in the list of recipients of CATAC products. Therefore representatives of both countries were invited to participates the CATAC/JICA courses. In February and March of 2025, the director of CATAC visited related scientific and civil protection institutions in both countries and discussed topics of interest.

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ANNEXES

I. Example Products

I.1 Example of Text products

Notre: These examples were generated in English for the Exercise CARIBEWAVE 25 and are used here in the Report to published in this language. The messages transmitted in real events to the users in Central America are formulated in Spanish. The Spanisch veriosn orf the present report contains the Spanish versions of these examples.

CATAC Message #1:
****

Central America Tsunami Advisory Center - CATAC

NOTICE : This message is published for information purposes only in support of Central American countries. National authorities are responsible for determining the level of alert and for taking appropriate measures for their country.

Tsunami Bulletin N° 01

Issued: 2025-03-20 09:03 Central American Time
2025-03-20 10:03 Panama Time
2025-03-20 15:03 UTC Time

An earthquake has occurred with the following these preliminary parameters:

Magnitude	: 8.0
Date	: 20/03/2025
Time	: 09:00 Central American Time,
	: 10:00 Panama Time, 15:00 UTC Time
Latitude	: 18.20 N
Longitude	: 75.37 W
Depth	: 25 Km
Location	: Jamaica Region

Assessment:
There is a high possibility of tsunami considering the magnitude, depth of the hypocenter, and the location of the earthquake.

Recommended Actions:

Immediate actions are urgently needed for the protection of the population on the Caribbean coasts of Central America.
More information will be provided in the next few minutes.

****

CATAC Message #2:

****

Central America Tsunami Advisory Center - CATAC

NOTICE : This message is published for information purposes only in support of Central American countries. National authorities are responsible for determining the level of alert and for taking appropriate measures for their country.

Tsunami Bulletin N° 02

Issued:	2025-03-21 09:09 Central American Time
	2025-03-21 10:09 Panama Time
	2025-03-21 15:09 UTC Time

An earthquake has occurred with the following parameters:

Magnitude	: 8.0
Date	: 20/03/2025
Time	: 09:00 Central American Time,
	: 10:00 Panama Time, 15:00 UTC Time
Latitude	: 18.20 N
Longitude	: 75.37 W
Depth	: 25 Km
Location	: Jamaica Region

Evaluation:

According to the analysis of the Moment Tensor of the earthquake there is a major possibility that a tsunami may have been produced which would affect with greater intensity the nearest coasts, about 100 km from the epicenter of the earthquake.
Authorities should take actions corresponding to their response plans

Tsunami simulation results:

Estimated Time of Arrival (ETA) in local time, Status and Maximum Height (AM) of tsunami waves, at different forecast points:

Site	Country	ETA (Local Time=	Status AM(m)

ISLA GRANDE	PANAMA	2025-03-20 11:45:30	Threat 1.45
TURTLE ISLAND	PANAMA	2025-03-20 11:45:00	Threat 1.28
COLON	PANAMA	2025-03-20 11:53:00	Threat 1.22
SAN BLAS	PANAMA	2025-03-20 11:50:30	Threat 1.11
LIMON	COSTA RICA	2025-03-20 11:13:00	Threat 0.93
VERAGUAS	PANAMA	2025-03-20 12:13:30	Threat 0.92

Graphical result:

Review in the attachment to this message, the color-coded forecast zones according to hazard,for the Caribbean Sea coastal areas of Central America according to our numerical tsunami simulations.

Updates:

More information will be provided in the next few minutes.

Countries may additionally receive messages from the Pacific Tsunami Warning Center (PTWC). In case of differences between 2024 and PTWC results, we recommend conservatively,the estimates that correspond to a higher hazard.

Additional information:

Detailed earthquake and tsunami information can be found at the website.
www.catac.ineter.gob.ni

****

CATAC Message #3

****

Central America Tsunami Advisory Center - CATAC

NOTICE : This message is published for information purposes only in
support of Central American countries. National authorities
are responsible for determining the level of alert and for
taking appropriate measures for their country.

Tsunami Bulletin N° 03

Issued: 2025-03-20 09:30 Central American Time
2025-03-20 10:30 Panama Time
2025-03-20 15:30 UTC Time

A tsunami warning is in effect for the coastal areas of Central American countries.

An earthquake has occurred with the following parameters:

Magnitude	: 8.0
Date	: 20/03/2025
Time	: 09:00 Central American Time,
	: 10:00 Panama Time, 15:00 UTC Time
Latitude	: 18.20 N
Longitude	: 75.37 W
Depth	: 25 Km
Location	: Jamaica Region

Evaluation:
Due to magnitude, depth and location of the earthquake there is a possibility that a tsunami may have been produced which would affect with greater intensity the closest coasts, about 100 km from the epicenter of the earthquake.
Authorities should take actions corresponding to their response plans.

Tsunami simulation results:
Estimated Time of Arrival (ETA) in local time, Status and Maximum Height (AM) of tsunami waves, at different forecast points:

Site	Country	ETA (Local Time)	Status	AM(m)
ISLA GRANDE	PANAMA	2025-03-20 11:45:30	Threat	1.45
TURTLE ISLAND	PANAMA	2025-03-20 11:45:00	Threat	1.28
COLON	PANAMA	2025-03-20 11:53:00	Threat	1.22
SAN BLAS	PANAMA	2025-03-20 11:50:30	Threat	1.11
LIMON	COSTA RICA	2025-03-20 11:13:00	Threat	0.93
VERAGUAS-CARIBE	PANAMA	2025-03-20 12:13:30	Threat	0.92

Graphical result:

Review in the attachment to this message, the color-coded forecast zones according to hazard,and wave heights, for the Caribbean Sea coastal areas of Central America estimated with numerical tsunami simulations.

Sea level station measurements:

Code	Coordinates	Country	ETA (Local Time)	AM(m)
VZ..ELPO	09.56°N 78.95°O	Panamá	2025-03-20 09:21	1.50
VZ..BDTO	09.35°N 82.26°O	Panamá	2025-03-20 09:56	1.30
VZ..LIMON	09.99°N 83.02°0	Costa Rica	2025-03-20 10:21	0.80

Updates:
More information will be provided in the next few minutes.

Countries may additionally receive messages from the Pacific Tsunami Warning Center (PTWC).
In case of differences between CATAC and PTWC results, we recommend conservatively, the estimates that correspond to a higher hazard.

Additional information:
Detailed earthquake and tsunami information can be found at the website.
http://catac.ineter.gob.ni/

****
CATAC Message #4:
****

Central America Tsunami Advisory Center - CATAC

NOTICE: This message is published for information purposes only in
support of Central American countries. National authorities
are responsible for determining the level of alert and for
taking appropriate measures for their country.

Tsunami Bulletin N° 04

Issued: 2025-03-20 10:00 Central American Time
2025-03-20 11:00 Panama Time
2025-03-20 16:00 UTC Time

A tsunami warning is in effect for the coastal areas of Central American countries.

An earthquake has occurred with the following parameters:

Magnitude	: 8.0
Date	: 20/03/2025
Time	: 09:00 Central American Time,
	: 10:00 Panama Time, 15:00 UTC Time
Latitude	: 18.20 N
Longitude	: 75.37 W
Depth	: 25 Km
Location	: Jamaica Region

Evaluation:

A tsunami was produced which affects or will affect the Caribbean coasts of Panama and Costa Rica.

Authorities should take actions corresponding to their response plans.

Tsunami simulation results:

Estimated Time of Arrival (ETA) in local time, Status and Maximum Height (AM) of tsunami waves, at different forecast points:

Site	Country	ETA (Local Time)	STATUS	AM(m)
ISLA GRANDE	PANAMA	2025-03-20 11:45:30	Threat	1.45
TURTLE ISLAND	PANAMA	2025-03-20 11:45:00	Threat	1.28
COLON	PANAMA	2025-03-20 11:53:00	Threat	1.22
SAN BLAS	PANAMA	2025-03-20 11:50:30	Threat	1.11
LIMON	COSTA RICA	2025-03-20 11:13:00	Threat	0.93
VERAGUAS-CARIBE	PANAMA	2025-03-20 12:13:30	Threat	0.92

Sea level station measurements obtained:

Code	Coordinates	Country	ETA (Local Time)	AM(m)
VZ..ELPO	09.56°N 78.95°O	PANAMA	2025-03-20 09:21	1.50
VZ..BDTO	09.35°N 82.26°O	PANAMA	2025-03-20 09:56	1.30
VZ..LIMON	09.99°N 83.02°0	COSTA RICA	2025-03-20 10:21	0.80

Updates:

More information will be provided in the next few minutes.

Countries may additionally receive messages from the Pacific Tsunami Warning Center (PTWC).
In case of differences between CATAC and PTWC results, we recommend conservatively,the estimates that correspond to a higher hazard.

Additional information:

Detailed earthquake and tsunami information can be found on the website.
http://catac.ineter.gob.ni/

****

CATAC Message #5:

****

Central America Tsunami Advisory Center - CATAC

NOTICE: This message is published for information purposes only in support of Central American countries. National authorities are responsible for determining the level of alert and for taking appropriate measures for their country.

Tsunami Bulletin N° 05

Issued :	2025-03-20 11:00 Central American Time
	2025-03-20 12:00 Panama Time
	2025-03-20 17:00 UTC Time

An earthquake has occurred with the following parameters:

Magnitude	: 8.0
Date	: 20/03/2025
Time	: 09:00 Central American Time,
	: 10:00 Panama Time, 15:00 UTC Time
Latitude	: 18.20 N
Longitude	: 75.37 W
Depth	: 25 Km
Location	: Jamaica Region

Evaluation: A tsunami was generated which affects the Caribbean coasts of Panama and Costa Rica. Observed Time of Arrival (ETA) in local time and Maximum Height (AM) of tsunami waves observed.

Code	Coordinates	Country	ETA (Local Time)	AM(m)
VZ..ELPO	09.56°N 78.95°O	PANAMA	2025-03-20 09:21	1.50
VZ..BDTO	09.35°N 82.26°O	PANAMA	2025-03-20 09:56	1.30
VZ..LIMON	09.99°N 83.02°0	COSTA RICA	2025-03-20 10:21	0.80
VZ..COIS	12.33°N 83.02°O	NICARAGUA	2025-03-20 10:45	0.30

Assessment:
According to our simulations, higher amplitudes could occur in the next few hours.
The national authorities of the different countries should make the appropriate decisions,according to their response plans.

PTWC messages:
Countries may additionally receive messages from the Pacific Tsunami Warning Center (PTWC).
In case of differences between CATAC and PTWC results, we recommend preferring conservatively,the estimates that correspond to a higher hazard.

I.2. Examples of CATAC graphic products

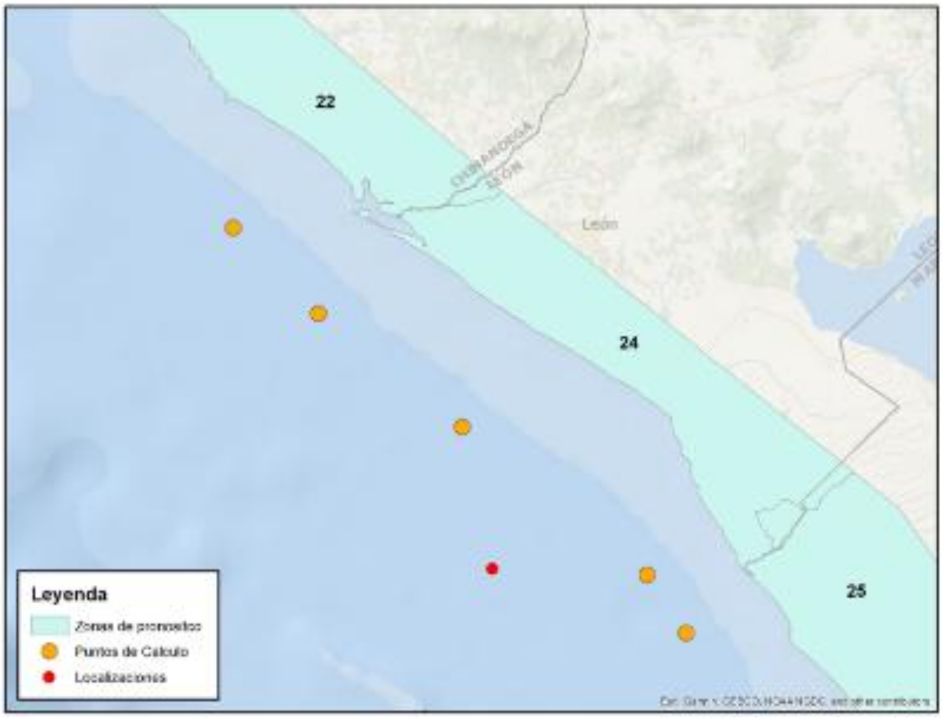

Figure 26. Coastal blocks and forecast points on the coast. Forecast points at 50 m depth. Definition of forecast zones at departmental level. Maximum values obtained for 70 forecast zones. For 130 forecast points on the Pacific and Caribbean coast.

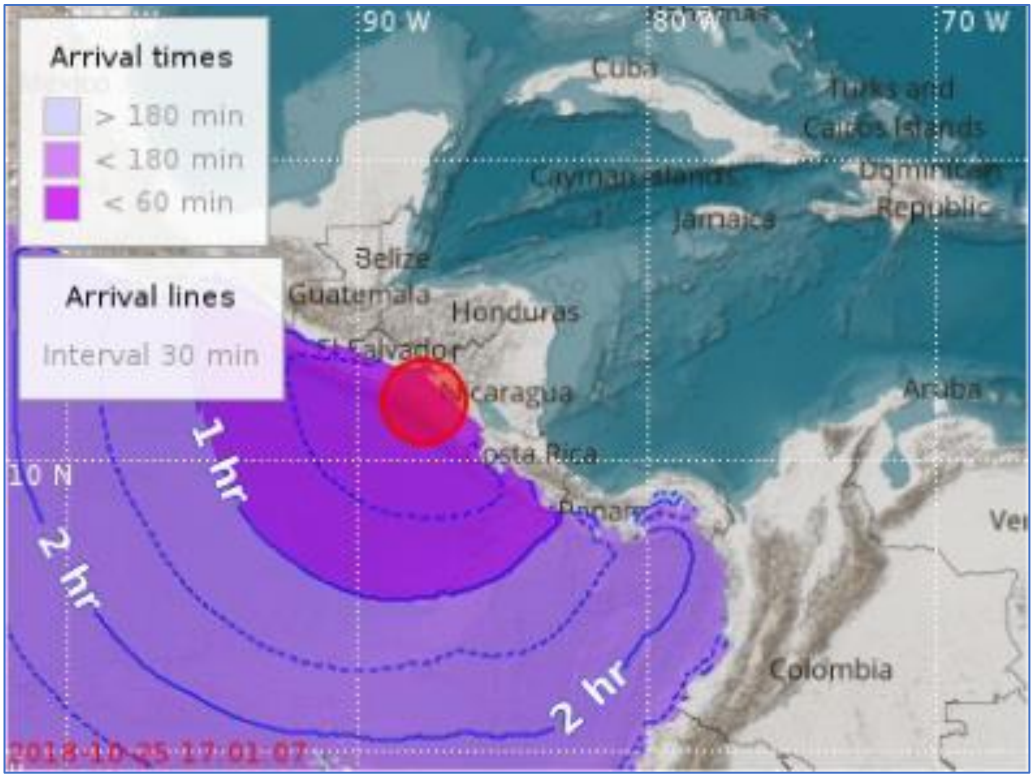

Figure27 . CATAC Tsunami arrival time forecast.

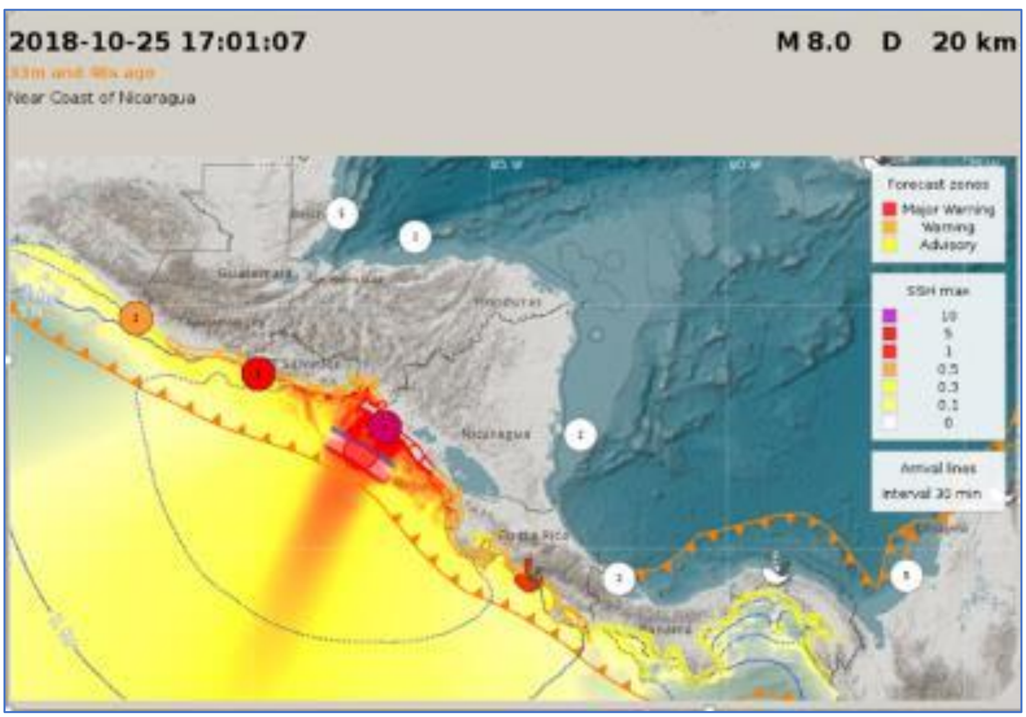

Figure 28. CATAC Tsunami coastal amplitude forecast.

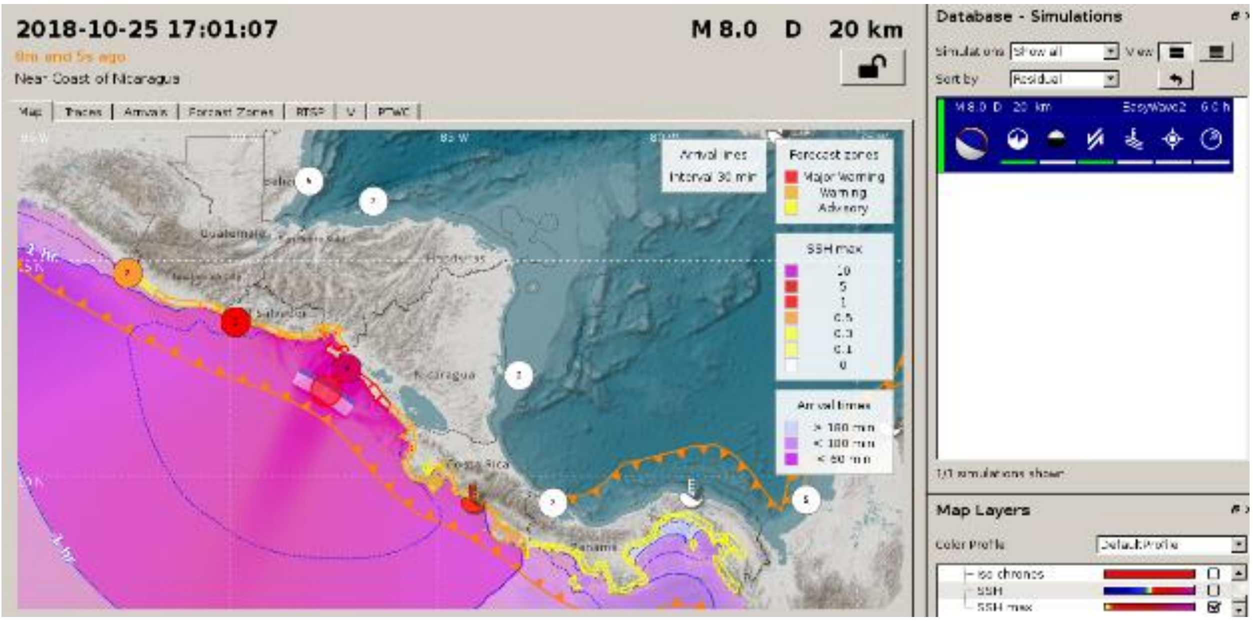

Figure 29. CATAC Deep-sea tsunami amplitude forecast.

Example of Text Message generated by TOAST at CATAC

Magnitude : 8.0 SR
Date : 10/25/2018
Time : 17:01:07 UTC
Latitude : 11.98 N
Length : 87.69 W
Depth : 20 Km
Event ID toast2018vamnlx M
Location : Near Coast of Nicaragua
Evaluation:
There is a Tsunami Possibility in the Following Areas:

T2 T1 T3 T4 Status Height COUNTRY LOCATION

2018-10-25 17:46:37 2018-10-25 17:01:07 2018-10-25 17:54:07 2018-10-25 23:01:07 Tsunami 5.08m NICARAGUA LEON
2018-10-25 17:47:37 2018-10-25 17:01:07 2018-10-25 21:44:37 2018-10-25 23:01:07 Tsunami 3.49m NICARAGUA CARAZO
2018-10-25 17:50:37 2018-10-25 17:01:07 2018-10-25 20:28:37 2018-10-25 23:01:07 Tsunami 3.03m NICARAGUA MANAGUA
2018-10-25 17:52:07 2018-10-25 17:01:07 2018-10-25 18:06:07 2018-10-25 23:01:07 Tsunami 3.03m NICARAGUA CHINANDEGA
2018-10-25 17:55:07 2018-10-25 17:01:07 2018-10-25 20:05:07 2018-10-25 23:01:07 Tsunami 2.51m NICARAGUA RIVAS
2018-10-25 18:55:07 2018-10-25 17:01:07 2018-10-25 22:53:07 2018-10-25 23:01:07 Tsunami 2.24m HONDURAS TIGER ISLAND
2018-10-25 18:19:37 2018-10-25 17:01:07 2018-10-25 18:46:07 2018-10-25 23:01:07 Tsunami 2.13m EL SALVADORCONCHAGUITA
2018-10-25 18:32:37 2018-10-25 17:01:07 2018-10-25 19:19:37 2018-10-25 23:01:07 Tsunami 2.11m EL SALVADORLA UNION
2018-10-25 17:42:37 2018-10-25 17:20:29 2018-10-25 21:16:07 2018-10-25 23:01:07 Tsunami 2.08m COSTA RICA GUANACASTE
2018-10-25 19:22:37 2018-10-25 17:08:23 2018-10-25 19:54:07 2018-10-25 23:01:07 Tsunami 2.01m HONDURAS VALLEY
2018-10-25 18:04:07 2018-10-25 17:01:07 2018-10-25 19:53:37 2018-10-25 22:37:07 Tsunami 1.97m EL SALVADORUSULUTLAN
2018-10-25 18:20:37 2018-10-25 17:01:07 2018-10-25 18:50:07 2018-10-25 22:45:37 Tsunami 1.95m EL SALVADORMEANGUERA DEL GOLFO
2018-10-25 17:53:37 2018-10-25 17:01:07 2018-10-25 21:43:37 2018-10-25 22:52:37 Tsunami 1.92m EL SALVADORSAN MIGUEL
2018-10-25 18:08:07 2018-10-25 17:04:07 2018-10-25 18:15:07 2018-10-25 22:57:37 Tsunami 1.90m EL SALVADORSAN VICENTE
2018-10-25 18:11:07 2018-10-25 17:12:35 2018-10-25 22:41:07 2018-10-25 23:01:07 Tsunami 1.90m EL SALVADORLA PAZ
2018-10-25 19:24:37 2018-10-25 17:01:07 2018-10-25 22:27:07 2018-10-25 23:01:07 Tsunami 1.87m HONDURAS CHOLUTECA
2018-10-25 18:34:07 2018-10-25 17:01:07 2018-10-25 18:39:37 2018-10-25 23:01:07 Tsunami 1.62m EL SALVADORISLA PUNTA ZACATE
2018-10-25 18:12:07 2018-10-25 17:01:07 2018-10-25 18:57:37 2018-10-25 22:54:07 Tsunami 1.48m NICARAGUA FARALLONES OF COSIGUINA
2018-10-25 18:00:37 2018-10-25 17:35:43 2018-10-25 22:08:37 2018-10-25 22:51:07 Tsunami 1.45m EL SALVADORLA LIBERTAD
2018-10-25 19:46:07 2018-10-25 17:48:29 2018-10-25 21:32:07 2018-10-25 23:01:07 Tsunami 1.25m GUATEMALA SANTA ROSA
2018-10-25 18:10:37 2018-10-25 17:59:35 2018-10-25 18:17:37 2018-10-25 22:48:37 Tsunami 1.16m GUATEMALA JUTIAPA
2018-10-25 18:11:37 2018-10-25 17:57:59 2018-10-25 18:15:07 2018-10-25 22:03:07 Tsunami 1.04m EL SALVADORAHUACHAPAN
2018-10-25 20:25:37 2018-10-25 18:13:05 2018-10-25 20:17:07 2018-10-25 23:01:07 Tsunami 1.03m GUATEMALA SUCHITEPEQUEZ
2018-10-25 18:00:07 2018-10-25 17:48:44 2018-10-25 22:46:37 2018-10-25 23:01:07 Tsunami 1.00m EL SALVADORSONSONATE
2018-10-25 18:20:07 2018-10-25 17:48:13 2018-10-25 22:56:37 2018-10-25 23:01:07 Tsunami 0.71m GUATEMALA ESCUINTLA
2018-10-25 18:12:37 2018-10-25 17:58:53 2018-10-25 18:43:37 2018-10-25 21:18:07 Tsunami 0.64m COSTA RICA COCOS ISLAND
2018-10-25 17:44:37 2018-10-25 17:35:17 2018-10-25 20:37:07 2018-10-25 23:01:07 Tsunami 0.64m COSTA RICA PUNTARENAS
2018-10-25 22:49:37 2018-10-25 18:15:35 2018-10-25 22:57:37 2018-10-25 22:54:37 Tsunami 0.58m GUATEMALA SAN MARCOS
2018-10-25 22:22:07 2018-10-25 17:47:29 2018-10-25 22:51:07 2018-10-25 23:01:07 Tsunami 0.56m COSTA RICA PUNTARENAS
2018-10-25 0:02:37 2018-10-25 17:49:13 2018-10-25 22:36:37 2018-10-25 23:01:07 Tsunami 0.54m COSTA RICA TURTLE ISLAND

II. Forecast Points

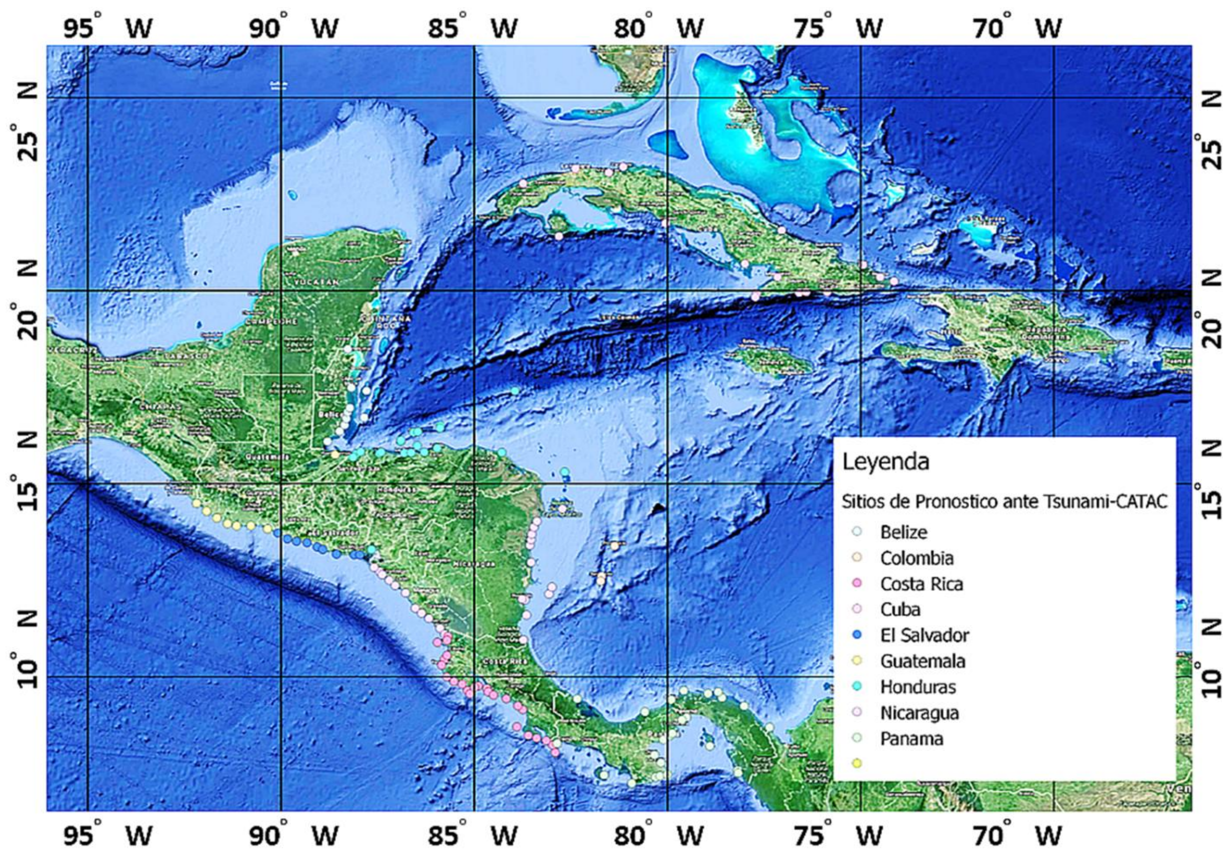

Figure 30. Map of Forecast points

List of Forecast Points

Country, Sitename. Latitude, Longitude

Costa Rica Abangaritos 10.1167 -85.0167 4
Costa Rica Agua Buena 8.4167 -83.3833 4
Costa Rica Agujas 9.7167 -84.6500 4
Costa Rica Ballena 9.1000 -83.7000 4
Costa Rica Bananito Sur 9.8667 -83.0000 4
Costa Rica Barmouth East 10.1167 -83.2333 4
Costa Rica Bonifacio 9.7833 -82.9167 4
Costa Rica Brasilito 10.4167 -85.7833 4
Costa Rica Brasilito 10.9833 -85.6833 4
Costa Rica Cabo Blanco 9.9333 -85.0000 4
Costa Rica Cabuya 9.6000 -85.0833 4
Costa Rica Cahuita 9.7333 -82.8500 4
Costa Rica Carrillo 9.8333 -85.3333 4
Costa Rica Catorce Millas 10.0833 -83.2000 4
Costa Rica Coco 10.5500 -85.7000 4
Costa Rica Colorado 10.1833 -85.1167 4
Costa Rica Colorado 10.7833 -83.6000 4
Costa Rica Comadre 9.7167 -82.8333 4
Costa Rica Conventillos 11.0833 -85.6833 4
Costa Rica Coronado 9.0500 -83.6167 4
Costa Rica Corozal 9.9833 -85.1667 4
Costa Rica Corralillo 9.8833 -84.7167 4
Costa Rica Culebre 10.6500 -85.6500 4
Costa Rica Curu 9.7833 -84.9333 4
Costa Rica Sunday 9.2500 -83.8667 4
Costa Rica El Tigre 10.7167 -85.6167 4
Costa Rica Esterillos East 9.5167 -84.5167 4
Costa Rica Garza 9.9000 -85.6500 4
Costa Rica Golfito 8.6333 -83.1667 4
Costa Rica Goschen 10.1667 -83.3167 4
Costa Rica Guerra 8.7667 -83.6167 4
Costa Rica Hacienda Santa Elena 10.9333 -85.8333 4
Costa Rica Hatillo 9.3000 -83.9000 4
Costa Rica Islita 9.8500 -85.4000 4
Costa Rica Jabilla 9.8167 -85.3000 4
Costa Rica Jaco 9.6167 -84.6333 4
Costa Rica La Abuela 9.7000 -85.0167 4
Costa Rica La Palma 8.6667 -83.4667 4
Costa Rica Las Mantas 9.7000 -84.6667 4
Costa Rica Lepanto 9.9333 -85.0333 4
Costa Rica Los Organos 9.8167 -84.9000 4
Costa Rica Madrigal 8.4500 -83.5167 4
Costa Rica Bad Country 9.6167 -85.1500 4
Costa Rica Manzanillo 9.7000 -85.2000 4
Costa Rica Marbella 10.0833 -85.7667 4
Costa Rica Matapalo 9.3333 -83.9667 4
Costa Rica Mexico 9.9833 -83.1333 4
Costa Rica Moin 10.0000 -83.0833 4

Costa Rica Montezuma 9.6500 -85.0667 4
Costa Rica Muneco 9.5500 -84.5500 4
Costa Rica Naranjo 9.9333 -84.9667 4
Costa Rica New Castle 9.9167 -83.0500 4
Costa Rica Nuevo Colon 10.5167 -85.7333 4
Costa Rica Palo Seco 8.6000 -83.4167 4
Costa Rica Paquera 9.8167 -84.9333 4
Costa Rica Paraiso 10.1833 -85.8000 4
Costa Rica Parismina 10.3000 -83.3500 4
Costa Rica Pigres 9.7833 -84.6333 4
Costa Rica Pital 9.7333 -84.6333 4
Costa Rica Pochotal 9.5833 -84.6167 4
Costa Rica Pochota 9.7500 -85.0000 4
Costa Rica Pochote 10.1500 -85.2833 4
Costa Rica Puerto Carazo 10.2167 -85.2500 4
Costa Rica Puerto Coyote 9.7833 -85.2667 4
Costa Rica Puerto Jimenez 8.5333 -83.3000 4
Costa Rica Puerto Limon 9.9833 -83.0333 3
Costa Rica Puerto Manzanillo 9.6333 -82.6500 4
Costa Rica Puerto Quepos 9.4167 -84.1500 4
Costa Rica Puerto Thiel 10.0333 -85.2000 4
Costa Rica Puerto Viejo 9.6333 -82.7500 4
Costa Rica Puerto Vlejo 10.3833 -85.8167 4
Costa Rica Punta Trinidad 10.0333 -85.7500 4
Costa Rica Puntarenas 9.9667 -84.8500 3
Costa Rica Quebrada Nando 9.7667 -85.2333 4
Costa Rica Quebrada Seca 9.8500 -85.3500 4
Costa Rica Quepos 9.4500 -84.1500 4
Costa Rica Refundores 10.3333 -85.8500 4
Costa Rica Rincon 8.6833 -83.4833 4
Costa Rica Rio Crande 9.6833 -85.0333 4
Costa Rica Rio Madre 10.0000 -83.1500 4
Costa Rica San Andres 9.8500 -82.9667 4
Costa Rica San Pedro 9.9667 -85.1500 4
Costa Rica San Rafael 10.2167 -83.3333 4
Costa Rica San Vicenta 9.7333 -85.0167 4
Costa Rica Santa Marta 9.9667 -85.6667 4
Costa Rica Santa Teresa 9.6500 -85.1833 4
Costa Rica Santiago 9.6667 -85.1833 4
Costa Rica Tarcoles 9.7667 -84.6167 4
Costa Rica Tigre 8.5500 -83.3667 4
Costa Rica Tuba Creek 9.7667 -82.9000 4
Costa Rica Uvita 9.1500 -83.7500 4
Costa Rica Venado 10.1667 -85.8167 4
Costa Rica Villalta 9.7333 -85.2000 4
Costa Rica Zancudo 8.5333 -83.1333 4
Costa Rica Zapotal 10.5000 -85.8000 4
Costa Rica Parismina 10.3156 -83.3515 0
Costa Rica Limon 9.9969 -83.0237 0
Costa Rica Puerto Viejo de Talamanca 9.6589 -82.7532 0
Costa Rica Manzanillo 9.6340 -82.6625 0
Guatemala Agua Caliente 15.6833 -88.5833 4
Guatemala Shipyard 13.8500 -90.3500 4
Guatemala Barra de la Gabina 13.7667 -90.1833 4
Guatemala Barra del Jiote 13.7833 -90.2167 4
Guatemala Barra Madre Vieja 14.0167 -91.4333 4
Guatemala Cabeza de Vaca 15.8833 -88.9500 4
Guatemala Cambalache 15.9167 -88.5667 4
Guatemala Champerico 14.2833 -91.9167 3
Guatemala Chapeton 13.8333 -90.3333 4
Guatemala Chicago 14.0833 -91.6000 4
Guatemala Churirin 14.1167 -91.6667 4
Guatemala El Arrenal 13.9167 -90.5833 4
Guatemala El Carrizal 13.9167 -90.9667 4
Guatemala El China 14.4167 -92.0500 4
Guatemala El Gariton 13.9167 -90.6000 4
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Guatemala El Semillero Barra Nahual. 14.0500 -91.5167 4
Guatemala Estero Lagarto 15.9333 -88.6000 4
Guatemala Hawaii 13.8667 -90.4000 4
Guatemala La Barrita 13.9167 -90.9167 4
Guatemala La Barrita 13.7667 -90.1667 4
Guatemala La Graciosa 15.8667 -88.5333 4
Guatemala La Isla 13.9167 -90.5167 4
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Guatemala La Pimienta 15.8333 -88.4667 4
Guatemala La Romana 15.7167 -88.6000 4
Guatemala La Verde 14.1833 -91.7500 4
Guatemala Las Escobas 15.6833 -88.6333 4
Guatemala Las Lagunas 13.9833 -91.3500 4
Guatemala Las Lisas 13.8000 -90.2667 4
Guatemala Las Quechas 13.9000 -90.5167 4
Guatemala Livingston 15.8167 -88.7500 4
Guatemala Machacas 15.7667 -88.5333 4
Guatemala Macho Creek 15.7667 -88.7167 4
Guatemala Mangrove 15.8833 -88.5000 4
Guatemala Nueva Venecia 14.0500 -91.5333 4
Guatemala Papaturro 13.9333 -90.6000 4
Guatemala Pato Creek 15.9167 -88.6000 4
Guatemala Pioquinto 15.7833 -88.5667 4
Guatemala Puerto Barrios 15.7167 -88.6000 3
Guatemala Puerto San Jose 13.9333 -90.8333 4
Guatemala Puerto Viejo 13.9333 -90.7000 4
Guatemala Punta del Cabo 15.9500 -88.5667 4
Guatemala Punta Herreria 15.8167 -88.7333 4
Guatemala Quehueche 15.8500 -88.7833 4
Guatemala Rio Blanco 15.8167 -88.7667 4
Guatemala Rio Salado 15.8000 -88.7167 4
Guatemala Rio San Carlos 15.7333 -88.6833 4
Guatemala San Francisco Madre Vieja 14.0333 -91.4500 4
Guatemala San Francisco del Mar 15.8333 -88.4167 4
Guatemala San Jose Buena Vista 13.8167 -90.3167 4
Guatemala San Jose Rama Blanca 13.9333 -91.2333 4
Guatemala San Juan 15.8500 -88.8833 4
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Guatemala Tecojate 13.9667 -91.3500 4
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Honduras Alligator Nose 16.4333 -86.2833 4
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Honduras Amapala 15.8500 -85.5500 4
Honduras Auaspani 15.2333 -84.8667 4
Honduras Auasta 15.2667 -84.8167 4
Honduras Aurata 15.4000 -84.1500 4
Honduras Awijiaratora 15.2500 -84.6000 4
Honduras Baja Mar 15.8833 -87.8500 4
Honduras Balfate 15.7667 -86.3833 4
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Honduras Close 15.6167 -84.0833 4
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Honduras Colorado 15.8167 -87.3000 4
Honduras Leather 15.7500 -87.1167 4
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Honduras Diamond Rock 16.4167 -86.3000 4
Honduras Dixon's Cove 16.3500 -86.5000 4
Honduras El Benk 15.1000 -83.3167 4
Honduras El Cacao 15.7833 -86.5333 4
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Honduras El Ojochalito 13.1333 -87.3667 4
Honduras El Paraiso 15.7500 -87.6500 4
Honduras El Peru 15.7833 -86.7500 4
Honduras El Porvenir 15.8333 -87.9333 4
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Honduras El Zapone 15.8667 -86.9000 4
Honduras First Bight 16.3833 -86.4000 4
Honduras Flowers Bay 16.2833 -86.6167 4
Honduras Gallinero 13.3167 -87.7500 4
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Honduras Guipo 13.1167 -87.4000 4
Honduras Huarta 15.8500 -84.6167 4
Honduras Iriona 15.8833 -85.2167 4
Honduras Ivas 15.8500 -84.8500 4
Honduras Jonesville 16.4000 -86.3667 4
Honduras Kanko 15.2000 -83.3667 4
Honduras Karasunta 15.1000 -83.3167 4
Honduras Kaski 15.3667 -83.6833 4
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Honduras La Ceiba 15.7833 -86.8000 3
Honduras La Laguna 15.9500 -85.9167 4
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Honduras Landa 15.8667 -85.5833 4
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Honduras Pakwi 15.1333 -83.3500 4
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Honduras Palmerson Point 16.4000 -86.4500 4
Honduras Palmira 15.7333 -86.9000 4
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Honduras Pital 15.9000 -86.0333 4
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Honduras Puerto Cortes 15.8500 -87.9500 3
Honduras Puerto Lempira 15.2500 -84.7833 3
Honduras Pulpito 16.4167 -86.2333 4
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Honduras Quiancan 15.3000 -83.5667 4
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Honduras Ras 15.8667 -84.7000 4
Honduras Ratlaya 15.5333 -83.9833 4
Honduras Raya 15.0667 -83.3000 4
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Honduras Salado Barra 15.7500 -87.0333 4
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Honduras San Lorenzo 13.4165 -87.4500 4
Honduras San Luis 15.0000 -83.2167 4
Honduras Sandy Bay 16.3500 -86.5833 4
Honduras Santa Rosa de Aguan 15.9500 -85.7167 4
Honduras Tauwanta 15.3000 -84.8500 4
Honduras Tela 15.7667 -87.4667 3
Honduras Titi 15.0833 -83.3167 4
Honduras Tocamacho 15.9833 -85.0167 4
Honduras Tomabe 15.7500 -87.5500 4
Honduras Travesia 15.8667 -87.9000 4
Honduras Trujillo 15.9167 -85.9667 3
Honduras Tusidaksa 15.1167 -83.3333 4
Honduras Twimawala 15.2833 -83.4833 4
Honduras Uhibila 15.4833 -83.9167 4
Honduras Usibila 15.2167 -83.3667 4
Honduras Venus 15.7833 -86.5167 4
Honduras Veracruz 15.6833 -88.1167 4
Honduras Vienna 15.9333 -85.8500 4
Honduras Vuelta Grande 15.9500 -85.7667 4
Honduras Walpatara 15.2167 -83.4000 4
Honduras West End 16.3000 -86.6137 4
Honduras Yahurabila 15.4000 -83.8000 4

Honduras Yamanta 15.2667 -83.4333 4
Honduras Zacate 15.7500 -86.9833 4
Honduras Omoa 15.7814 -88.0511 0
Honduras Puerto Cortez 15.8232 -87.9403 0
Honduras Tela 15.7841 -87.4807 0
Honduras El Triunfo de La Cruz 15.7841 -87.4807 0
Honduras La Ceiba 15.7841 -87.4807 0
Honduras Utila Island/Pumpkin Hill 16.1229 -86.8825 0
Honduras Utila/Utila Island 16.0968 -86.8968 0
Honduras Roatan Island/West Bay 16.2767 -86.6003 0
Honduras Roatan/Roatan Island 16.2767 -86.6003 0
Honduras Roatan Island/Sandy Bay 16.3317 -86.5673 0
Honduras Roatan Island/Punta Gorda 16.4164 -86.3658 0
Honduras Roatan/Oakridge Island 16.3900 -86.3533 0
Honduras Roatan Island/Camp Bay Beach 16.4293 -86.2907 0
Honduras Roatan Island/Barbareta Island 16.4303 -86.1425 0
Honduras Guanaja Island/Jim Bodden 16.4532 -85.9162 0
Honduras Guanaja Island/Airport 16.4532 -85.9162 0
Honduras Bonacca Island 16.4420 -85.8857 0
Honduras Guanaja Island/ Mangrove B. 16.5008 -85.8685 0
Honduras Guanaja Island/ Savannah B. 16.4841 -85.8444 0
Honduras Swan Island 17.4014 -83.9436 0
Honduras Cayos Cochino Grande 15.9702 -86.4718 0
Honduras Trujillo 15.9349 -85.9652 0
Honduras Limón 15.8675 -85.5006 0
Honduras Punta Piedra 15.8891 -85.2406 0
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Honduras Lempira(Kaski) 15.3796 -83.6849 0
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Nicaragua Aposentillo 12.6333 -87.3667 0
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Nicaragua Auastara 14.3833 -83.2333 0
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Nicaragua Barra del Rio 11.2833 -83.8833 0
Nicaragua Bismuna Tara 14.7500 -83.4167 0
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Nicaragua Bluefields 12.0400 -83.7700 0
Nicaragua Brito 11.3500 -85.9667 0
Nicaragua Cabo Gracias a dios 14.9833 -83.1667 0
Nicaragua Cayos Misquitos 14.3665 -82.7433 0
Nicaragua Cano Mocho 12.1167 -83.8167 0
Nicaragua Casares 11.6500 -86.3500 0
Nicaragua Corinto 12.4833 -87.1833 0
Nicaragua Corn Island 12.1766 -83.0317 0
Nicaragua Little Corn Island 12.2898 -82.9759 0
Nicaragua Dakura 14.4000 -83.2167 0
Nicaragua El Carmen 12.3500 -86.9667 0
Nicaragua El Chaparral 12.2833 -86.8833 0
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Nicaragua El Ostional 11.1000 -85.7667 0
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Nicaragua El Realejo 12.5333 -87.2000 0
Nicaragua El Soccoro 11.2167 -85.8167 0
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Nicaragua Fatima 12.5667 -87.2333 0
Nicaragua Greystown 14.4500 -83.2833 0
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Nicaragua Jiquilillo 12.7333 -87.4333 0
Nicaragua Kakabila 12.4000 -83.7333 0
Nicaragua Karawala 12.8833 -83.5833 0
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Nicaragua Kukra Hill 12.1333 -83.7000 0
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Nicaragua La Flor 11.1333 -85.7833 0
Nicaragua Pearl Lagoon 12.3333 -83.6833 0
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Nicaragua Li-Dakira 14.4667 -83.2667 0
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Nicaragua Potosi 13.0167 -87.5333 0
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Nicaragua Puerto Arturo 12.8500 -87.5000 0
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Nicaragua Puerto Isabel 13.3667 -83.5667 0
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Nicaragua San Antonio 12.0667 -83.8833 0
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Nicaragua Set Net 12.4333 -83.5000 0
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Nicaragua Wankluma 13.2167 -83.5833 0
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Nicaragua Uskira 14.4833 -83.2833 0
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Panama Belen 8.8667 -80.8667 4
Panama Bella Vista 9.2167 -82.3000 4
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Panama Big Creek 9.3667 -82.2500 4
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Panama Boca de Daria 8.9500 -82.0167 4
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Panama Palo Grande 8.8667 -79.2167 4
Panama Panama 8.9700 -79.5300 0
Panama Patino 8.2500 -78.2833 4
Panama Paunch 9.3833 -82.2500 4
Panama Pedasi 7.5333 -80.0333 4
Panama Pena Blanca 8.8967 -79.7833 4
Panama Perrecenega 8.3500 -78.1667 4
Panama Pigeon Creek 9.2500 -82.2667 4
Panama Pilon 9.1833 -80.2000 4
Panama Piloncito 9.1833 -80.2167 4
Panama Pito 8.6833 -77.5333 4
Panama Pitshis Creek 9.1833 -82.3333 4
Panama Pixvae 7.8333 -81.5833 4
Panama Playa Bugori 9.1167 -81.9000 4
Panama Playa Colorada 9.0500 -81.7667 4
Panama Playa Colorada 8.6667 -78.6167 4
Panama Playa Floral 8.4167 -78.9667 4
Panama Playa Gallinaza 9.1333 -81.9167 4
Panama Playa Mananti 8.9500 -82.0000 4
Panama Playon Chico 9.3000 -78.2333 4
Panama Portobelo 9.5500 -79.6500 4
Panama Porvenir 9.3500 -82.2333 4
Panama Pueblo Viejo 9.1833 -80.1833 4
Panama Puerto Armuelles 8.2833 -82.8667 3
Panama Puerto Barrero 7.8833 -81.1500 4
Panama Puerto Escondido 8.0167 -78.4167 4
Panama Puerto Escondido 8.9833 -81.7667 4
Panama Puerto Mariato 7.6667 -81.0000 4
Panama Puerto Naranjo 7.2667 -80.9167 4
Panama Puerto Obaldia 8.6667 -77.4167 4
Panama Puerto Pilon 9.3667 -79.7833 4
Panama Puerto Pina 7.5833 -78.1833 4
Panama Puerto Ventura 9.4500 -82.4500 4
Panama Punta Alegre 8.2833 -78.2500 4
Panama Punta Chame 8.6500 -79.7000 4
Panama Punta de Burica 8.0333 -82.8833 4
Panama Punta del Medio 9.2500 -80.0667 4
Panama Punta Laurel 9.1500 -82.1333 4
Panama Punta Mala 7.4667 -80.0000 4
Panama Punta Robalo 9.0333 -82.2500 4
Panama Quebrada de Tallo 8.0833 -82.8833 4
Panama Quebrada Grande 9.1333 -80.3667 4
Panama Quebrada la Yeguada 7.6833 -80.1167 4
Panama Rafaelito 8.2500 -78.9167 4
Panama Rio Alejandro 9.3833 -79.7833 4
Panama Rio Azucar 9.4333 -78.6333 4
Panama Rio Canaveral 9.0167 -81.7167 4
Panama Rosarito 7.8500 -81.5667 4
Panama Saboga 8.6167 -79.0667 4
Panama San Carlos 8.4833 -79.9667 4
Panama San Buenaventura 8.5000 -78.5000 4
Panama San Miguel 8.4500 -78.9333 4
Panama San Miquelito 9.0333 -79.5000 2
Panama Santa Ana Arriba 7.9333 -80.3667 4
Panama Santa Catalina 7.6333 -81.2667 4
Panama Santa Catalina 8.7667 -81.3333 4
Panama Santa Clara 8.3833 -80.1167 4
Panama Santa Isabel 9.5333 -79.1833 4
Panama Secretary 9.0500 -81.8500 4
Panama Senon 8.4167 -78.1500 4
Panama Sevilla 8.2500 -82.4000 4
Panama Shark Hole 9.2167 -82.2167 4
Panama Short Cut 9.3333 -82.1833 4
Panama Sukunya 8.8333 -77.6333 4
Panama Taimati 8.1500 -78.2333 4
Panama Tarascon 9.2500 -80.0500 4
Panama Tembladera 8.6833 -79.7667 4
Panama Plan Terminal 9.1833 -80.2000 4
Panama Ticantiqui 9.4000 -78.4667 4
Panama Tubuala Numero Uno 8.9167 -77.7333 4
Panama Ustupo 9.1333 -77.9333 4
Panama Ustupo Yantupo 9.1167 -77.9333 4
Panama Varadero 7.2833 -80.9000 4
Panama Veraguas 8.8667 -80.9000 4
Panama Viento Frio 9.5833 -79.4000 4
Panama Playa Boca del Drago 9.4178 -82.3322 0
Panama Bocas del Toro 9.4178 -82.3322 0
Panama Kusapin 9.1834 -81.8866 0
Panama Veraguas 8.8735 -80.9050 0
Panama Cocle del Norte 9.0784 -80.5715 0
Panama Palmas Bellas 9.2333 -80.0880 0
Panama Colon 9.3558 -79.9068 0
Panama Puertobelo 9.5553 -79.6570 0
Panama Grande Island 9.6369 -79.5635 0
Panama Viento Frio 9.5857 -79.4073 0
Panama Palenque 9.5742 -79.3603 0
Panama El Porvenir 9.5597 -78.9477 0
Panama Porvenir Islands 9.6056 -78.7000 0
Panama Tiger Island 9.4345 -78.5211 0
Panama Playon Chico 9.3098 -78.2328 0
Panama Achutupu 9.2001 -77.9875 0
Panama Ustupo 9.1370 -77.9249 0
El Salvador Acajutla 13.5833 -89.8333 3
El Salvador Conchaguita 13.2333 -87.7667 4
El Salvador Condadillo 13.2000 -87.9333 4
El Salvador El Limon 13.2500 -88.4167 4
El Salvador El Majahual 13.5000 -89.3667 4
El Salvador El Naranjo 13.1833 -88.2500 4
El Salvador El Porvenir 13.7167 -90.0500 4
El Salvador El Sunzal 13.5000 -89.3833 4
El Salvador Garita Palmera 13.7333 -90.0833 4
El Salvador La Libertad 13.8167 -89.3333 3
El Salvador La Union 13.3333 -87.8500 3
El Salvador Las Piedras 13.5333 -89.6333 4
El Salvador Los Jiotes 13.4500 -87.8500 4
El Salvador Mejicanos 13.7333 -89.2000 2
El Salvador Metalio 13.6167 -89.8833 4
El Salvador Monte Verde 13.4167 -87.8833 4
El Salvador Montecristo 13.2500 -88.8000 4
El Salvador Punta Remedios 13.5333 -89.8000 4
El Salvador Salinas de Sisiguayo 13.2833 -88.6833 4
El Salvador Sitio de Santa Lucia 13.2833 -88.5500 4

III. Observation Sites

A table of the observation sites used by CATAC can be obtained from its webpage http://catac.ineter.gob.ni .

IV. NTWC and TWFP in Central America

CATAC is cooperating with the following institutions:

1. **NTWC and other institutions responsible for scientific monitoring from which CATAC receives seismic and geophysical data**

1.1 Nicaragua: INETER, CATAC
For Nicaragua, CATAC itself acts as NTWC issuing messages to the Government of Nicaragua, the Emergency Operations Center (CODE) of the National System for Disaster Prevention, Mitigation and Response (SINAPRED) and Civil Defense of the Nicaraguan Army according to the national SOPs of Nicaragua. From 2023 onwards, CATAC directly sends Earthquake and Tsunami messages to the population.

1.2 El Salvador: Ministry of Environment and Natural Resources (MARN), General Directorate of the Environmental Observatory (MARN-DGOA).

1.3 Guatemala: National Institute of Seismology, Volcanology, Meteorology and Hydrology (INSIVUMEH).

1.4 Honduras: a) Permanent Contingency Commission (COPECO). In Honduras there is no scientific institution with the capacity to evaluate the tsunami threat. COPECO maintains the seismic network of the country. **b)** Geophysical Institute, University of Honduras. Maintains the seismic network of UNAH

1.5 Costa Rica: National System for Tsunami Monitoring (SINAMOT) at the National University (UNA). SINAMOT receives seismological products from Volcano and Earthquake Observatory of Costa Rica ((OVSICORI, at UNA) and National Seismic Network (RSN, Universidad de Costa Rica). CATAC is streaming seismic data from OVSICORIU and RSN.

1.6 Panama: Institute of Geosciences of the University of Panama (IGC-UPA);
CATAC is streaming seismic waveform data from
a) Institute of Geosciences of the University of Panama (IGC-UPA);
b) Authority of the Panama Canal (ACP)
c) Baru seismic network (private institution)

2. TWFP or Organizations in charge of issuing Tsunami Warnings to the population:

2.1 Nicaragua:

a) As of 2023, CATAC itself directly sends Earthquake and Tsunami messages to the population.

b) National System for Disaster Prevention, Mitigation and Response (SINAPRED).

2.2 El Salvador: Ministry of the Interior, General Directorate of Civil Protection and Disaster Prevention and Mitigation (DGPC).

2.3 Guatemala: National Coordinator for Disaster Reduction (CONRED).

2.4 Honduras: Permanent Contingency Commission (COPECO)

2.5 Costa Rica: National Commission for Risk Prevention and Emergency Attention (CNE).

2.6 Panama: National Civil Protection System (SINAPROC).

2. Regional institution related to disaster prevention including tsunamis

CEPREDENAC; Center for Disaster Prevention in Central America

Coordination of disaster prevention measures and the establishment of a common politics on disaster prevention and mitigation

Receives CATAC messages, it is planned to integrate CATAC products in their Website.