6.2 Central American Tsunami Advisory Center (CATAC)

established at INETER, Nicaragua

Dr. Wilfried Strauch

CATAC Coordinator, INETER

wilfried.strauch@yahoo.com

http://catac.ineter.gob.ni

Tsunami Advisory Center for Central America (CATAC)

(pilot operation from 2019)

- 400 seismic stations in Central America (+ 200 global via IRIS)
- 24x7 Two watchstanders(group of 16)
- Seismological processing (SeisComP PRO)
- Tsunami Evaluation (SeisComP TOAST & Database)
- Initial alert message in 2 minutes
- Tsunami parameter message in less than 10 minutes

<u>Addressees</u>

- 11 monitoring/scientific institutions
- 9 civil protection agencies
- 1 regional coordinating body (CEPREDENAC)

- Institutional (CEPREDENAC-SICA)
- Projects: JICA, UNESCO, SDC
- Procedures
- Training and Technology

CATAC Web site http://catac.ineter.gob.ni

Results

- - Earthquake Viewer
- - Seismic Re-Locator
- - Seismic station viewer
- - Seismogram viewer
- - Shakemaps
- - Tide stations
- - Earthquake Map
- - Seismological Communiqué

Tools

- - GAPS - Seismological processing
- - GDS - Messenger
- - FDSNWS - fdsnws Graphic Terminal
- - FDSNWS - fdsns web services, metadata
- - QuakeLink - Seismic Event Service
- - Capacitation

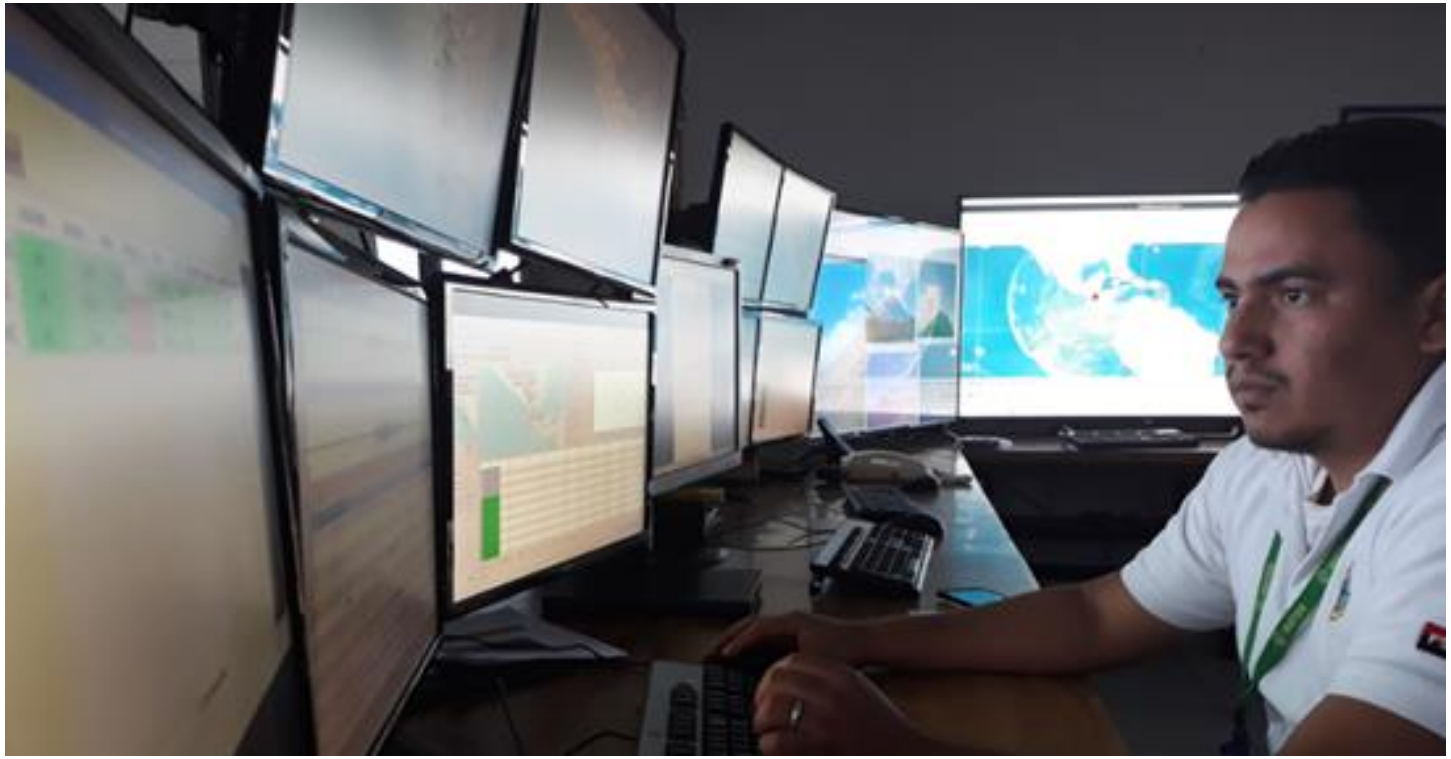
Docs

- - Project with JICA
- - プロジェクト概要
- - CATAC User Guide
- - Tsunami Threat Central America
- - INETER Publications
- - CA-19 Drill (19 Aug 2019)
- - CA-20 Drill (11 Nov 2020)
- - Software documentation

CATAC, Processing and Alert Room

. CATAC, Situation and meeting room

Operators



The seismologists of the 24x7 service review the automatic results and perform manual processing.
They must publish the initial products within 2 minutes after the earthquake occurs.

Main Systems for CATAC operations

- **SeisComP**
  - Automatic & Interactive seismological processing
  - Calculation of the Momentum Tensor from which the Magnitude Mw is derived
  - Sending seismological and tsunami messages (on seismological basis)

- **Tsunami database** with pre-calculated solutions
  (in the moment not used due to bugs detected)

- **TOAST**
  - Numerical tsunami simulation
  - Sending of simulation product messages, arrival times and amplitudes
  - Processing of tide gauge records

CATAC Performance Indicators and the values to be achieved in its initial/experimental operation phase and in the fully implemented phase.

Performance indicators	**Values achieved during preliminary operations until 2019**	**Values to be achieved after final implementation As of 2020**
Time elapsed from earthquake to emission of initial tsunami products with preliminary earthquake parameters 2.	5 minutes	**2 minutes**
2. Probability of detection of earthquakes with magnitude Mw>=6.0.	100%	**100%**
3. Accuracy of preliminary earthquake parameters in: hypocenter location/magnitude/depth.	0.3degree/0.3/<30km	**0.2degree/0.2/<20km**
5. Accuracy of Estimated Time of Arrival in the event of a tsunami	10% of travel time travel time	**10% of travel time travel time**
6. Percentage of Member States receiving products shipped by CATAC	100%	**100%**
7. Percentage of time that CATAC is operating and able to respond to a tsunami event.	100%	**100%**
8. Frequency of regular communication tests	Twice a year	**Four times a year**

Genic Tsunami Potential adopted by CATAC

based on seismological parameters

Magnitude (Mw)	Tsunami Potential Description
$4.5 \leq M_w \leq 7.0$	There is no tsunami threat from this earthquake.
$7.1 \leq M_w \leq 7.5$ **and under the sea;** **and depth less than 100km**	Possibility of a destructive local tsunami confined to distances of 100-300 km from the epicenter.
$M \geq 7.6_w$ **and under the sea;** **and depth less than 100km**	Possibility of a destructive tsunami all along the coast

Criteria adopted by CATAC

Type of Newsletter	Message	Criteria	Content	Weather
Seismological information	Early Warning Earthquake Early Warning	**ML 4.5** and above	Location, depth and magnitude Predicted intensities	Less than 0.5 min
	Seismological message	**ML 4.5** and above	Location, depth and magnitude, Observed intensities	1-2 min
Tsunami Information	Only one bulletin	**ML 6.0-6.4**; or underground; o depth≥100km	Earthquake parameters and declaration No tsunami hazard	1-2 min
	Only one bulletin if no minor reportable waves observed	**MW 6.5-6.9**	Earthquake parameters (Magnitude Mw) and 'No Tsunami Hazard' statement	5-10 min
Tsunami Hazard Message	Bulletin with quantitative prediction	**Mw 7.0 and above**	Earthquake parameters and quantitative prediction of hazard level and estimated time of arrival (ETA).	5-10 min
	Supplementary with comments	Complex earthquakes, Mega earthquake, Tsunamis for which amplitudes are predicted to increase after several hours.	Earthquake parameters, quantitative prediction and tide gauge observations	When there is a revision of the earthquake or tsunami prediction, or of observations

Emergence of CATAC

1992 Disastrous tsunami in Nicaragua

1993 Nicaragua begins active cooperation with ICG/PTWS

1996 NTWC established in Nicaragua, first in Central America

2003 CEPREDENAC Decision on the Development of a Regional Tsunami Warning System

2003 ICG/PTWS-WG-CA training to support this process

Images of destructive tsunamis shock the world:

2004 South Asia - 2010 Chile - 2011 Japan

2009/2011/2014 WG-CA meetings.... Nicaragua offers to establish CATAC

2015 CEPREDENAC country representatives "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 elevate it to SICA".

- 2015 Creation of CATAC accepted by ICG/PTWS, Caribbean EWS and IOC Assembly

Development of CATAC

2016 Nicaragua creates CATAC at INETER

2016 Nicaragua requests support from Japan for the development of CATAC

2016 CATAC Strengthening Project Begins

Training, procurement of software and equipment, installation, installation

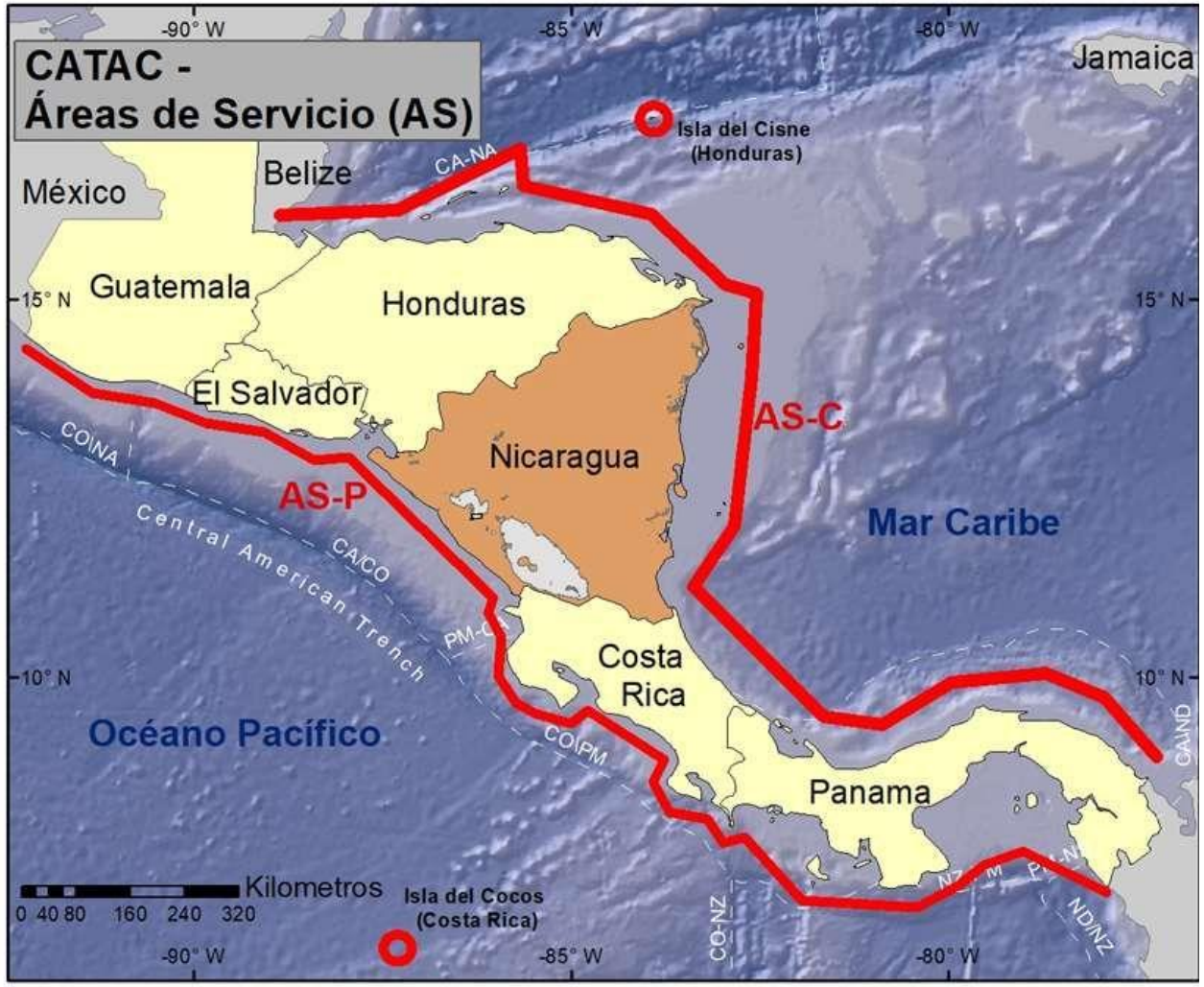
2016-2019 other projects support CATAC (UNESCO, EWARNICA)

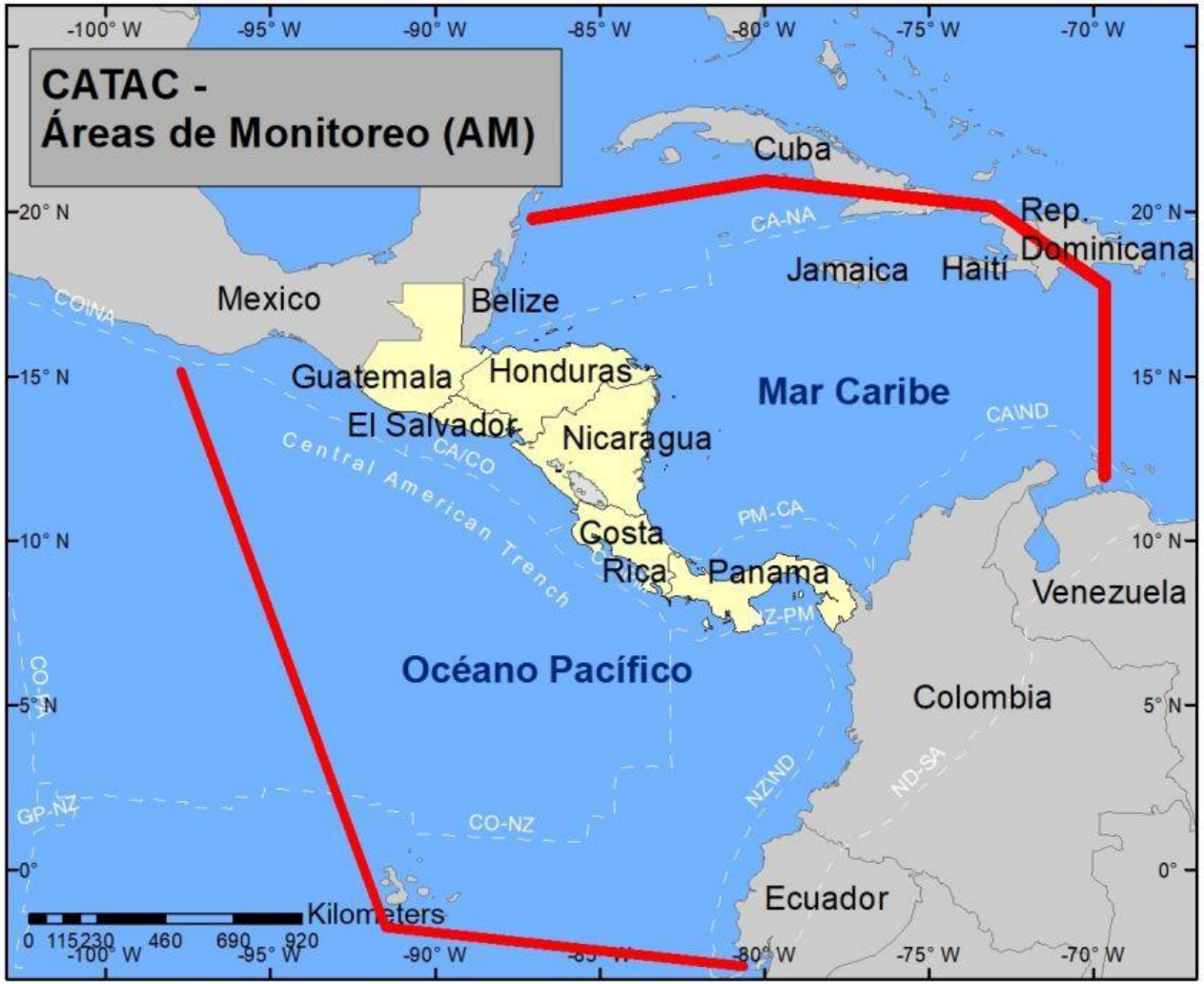
2019 Completion of CATAC reinforcement project with Japan

2019 ICG/PTWS and ICG/Caribbean EWS accept experimental CATAC operation

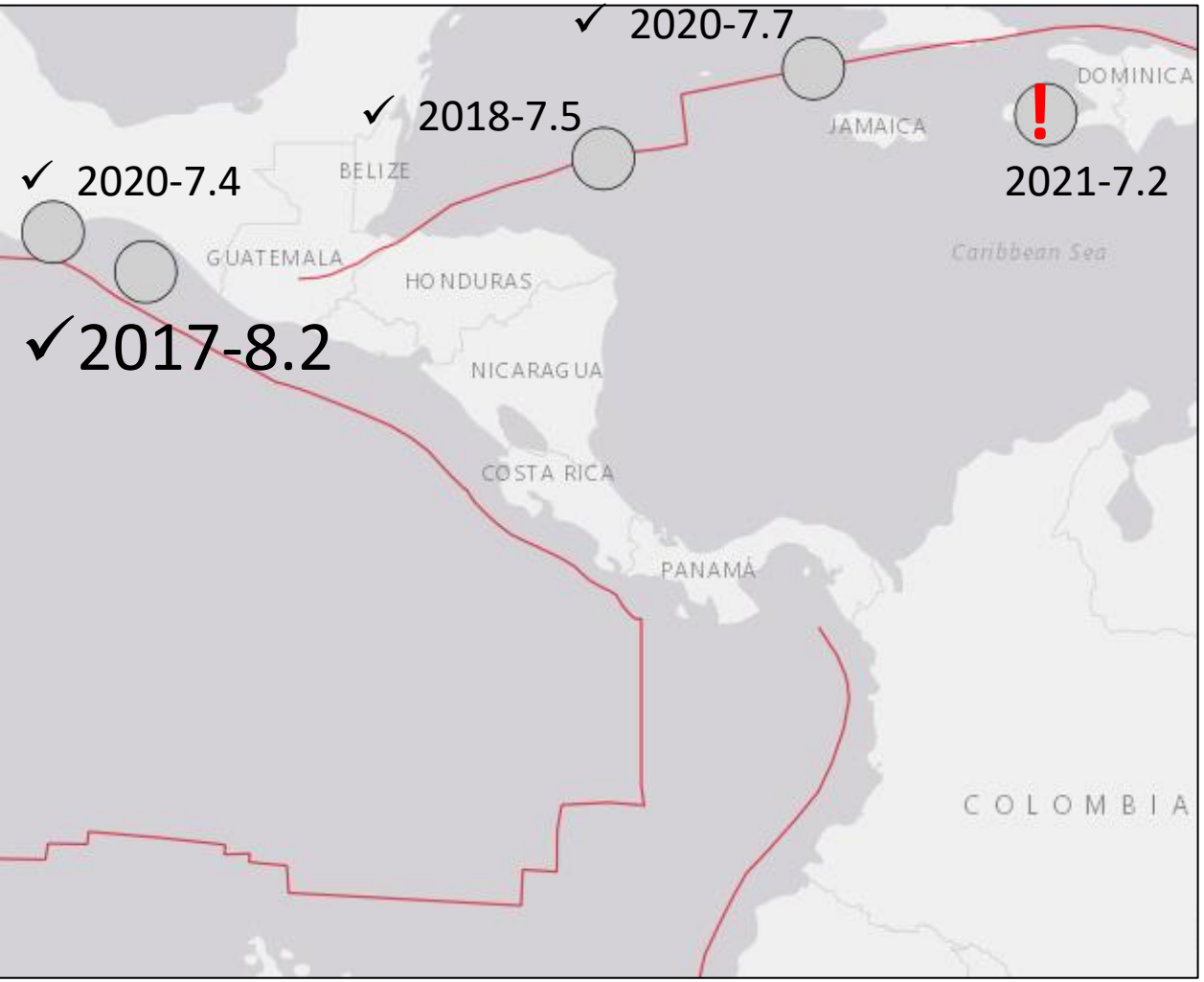
2021/Dec ICG/PTWS accepts full operation of CATAC in interim mode

CATAC service areas and monitoring zones





Experience with the processing of earthquakes larger than M7

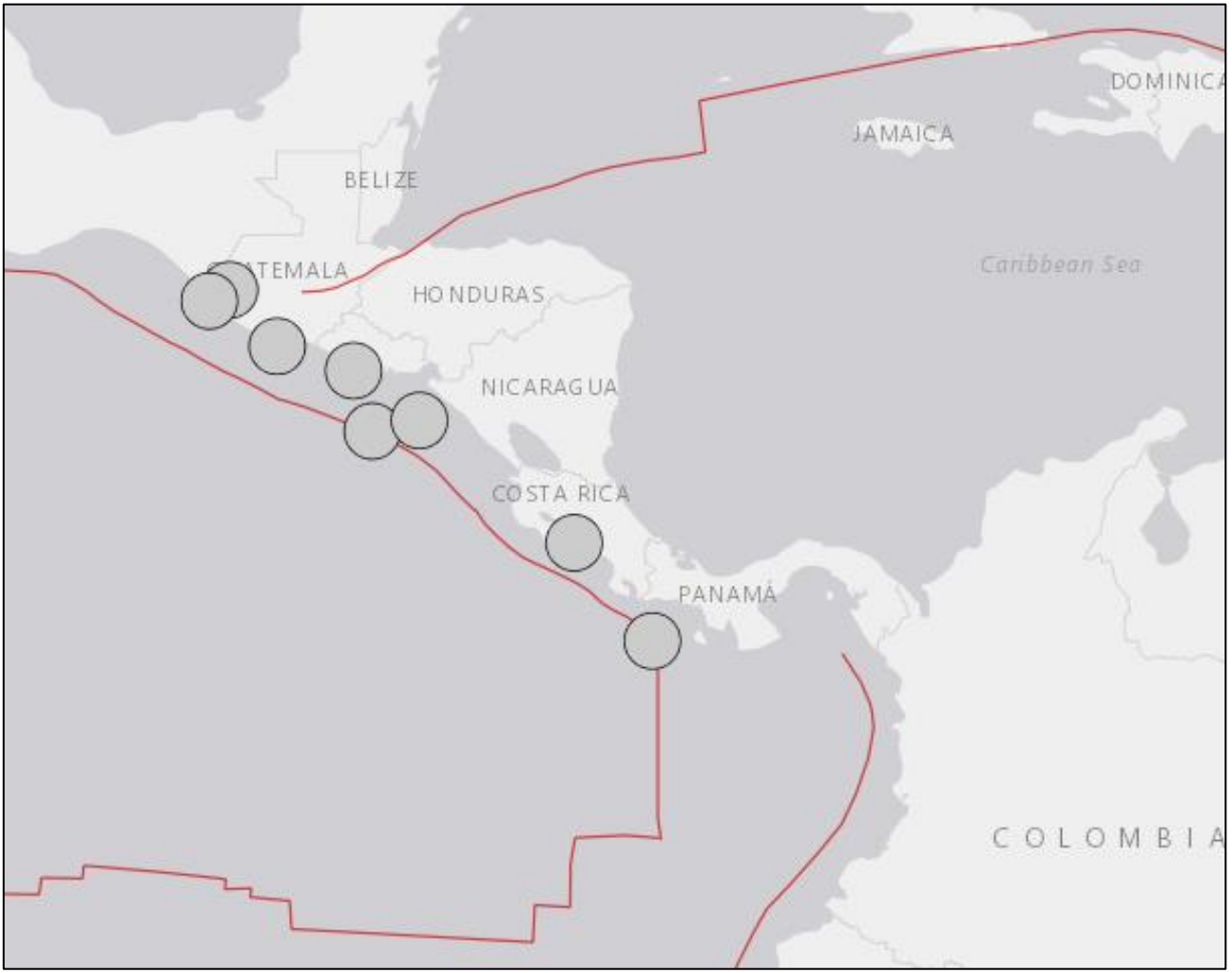


These seismic events were processed and CATAC products were sent to the recipients in an informal manner.
By Whatsapp and email.

In case of the 2021 Haiti earthquake, there was a problem in immediate processing due to lack of nearby non-saturated stations....

The earthquake was re-processed -see results in a separate presentation.

2016-2021 Experience with M6.5 - M7 (NEIC) earthquake processing.

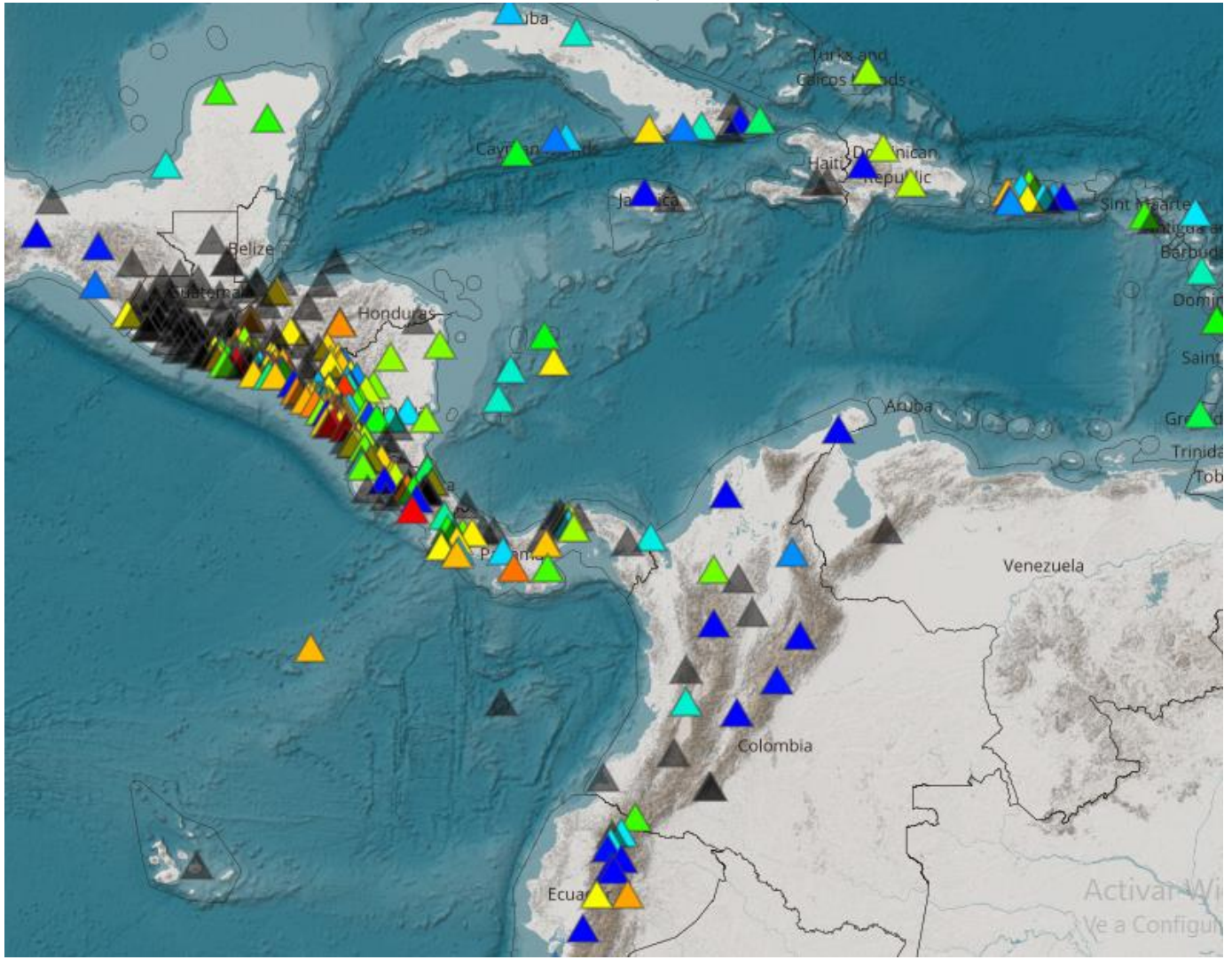


Seisms were processed and seismological products were sent to the recipients.

M6.9 156 km SSW of Puerto El Triunfo, El Salvador
2016-11-24 18:43:47 (UTC) 10.0 km
M6.9 2 km SSW of San Pablo, Guatemala
2017-06-14 07:29:04 (UTC) 93.0 km
M6.8 28 km SW of Puerto San José, Guatemala
2017-06-22 12:31:03 (UTC) 38.1 km
M6.5 18 km W of Parrita, Costa Rica
2017-11-13 02:28:23 (UTC) 19.4 km
M6.7 5 km SW of Puerto Madero, Mexico
2019-02-01 16:14:12 (UTC) 66.0 km

M6.6 32 km S of La Libertad, El Salvador
2019-05-30 09:03:32 (UTC) 57.9 km
M6.7 71 km S of Burica, Panama
2021-07-21 21:15:12 (UTC) 10.0 km
M6.5 80 km SW of Jiquilillo, Nicaragua
2021-09-22 09:57:07 (UTC) 21.0 km

Location of seismic stations in and around Central American countries used by CATAC, 2023



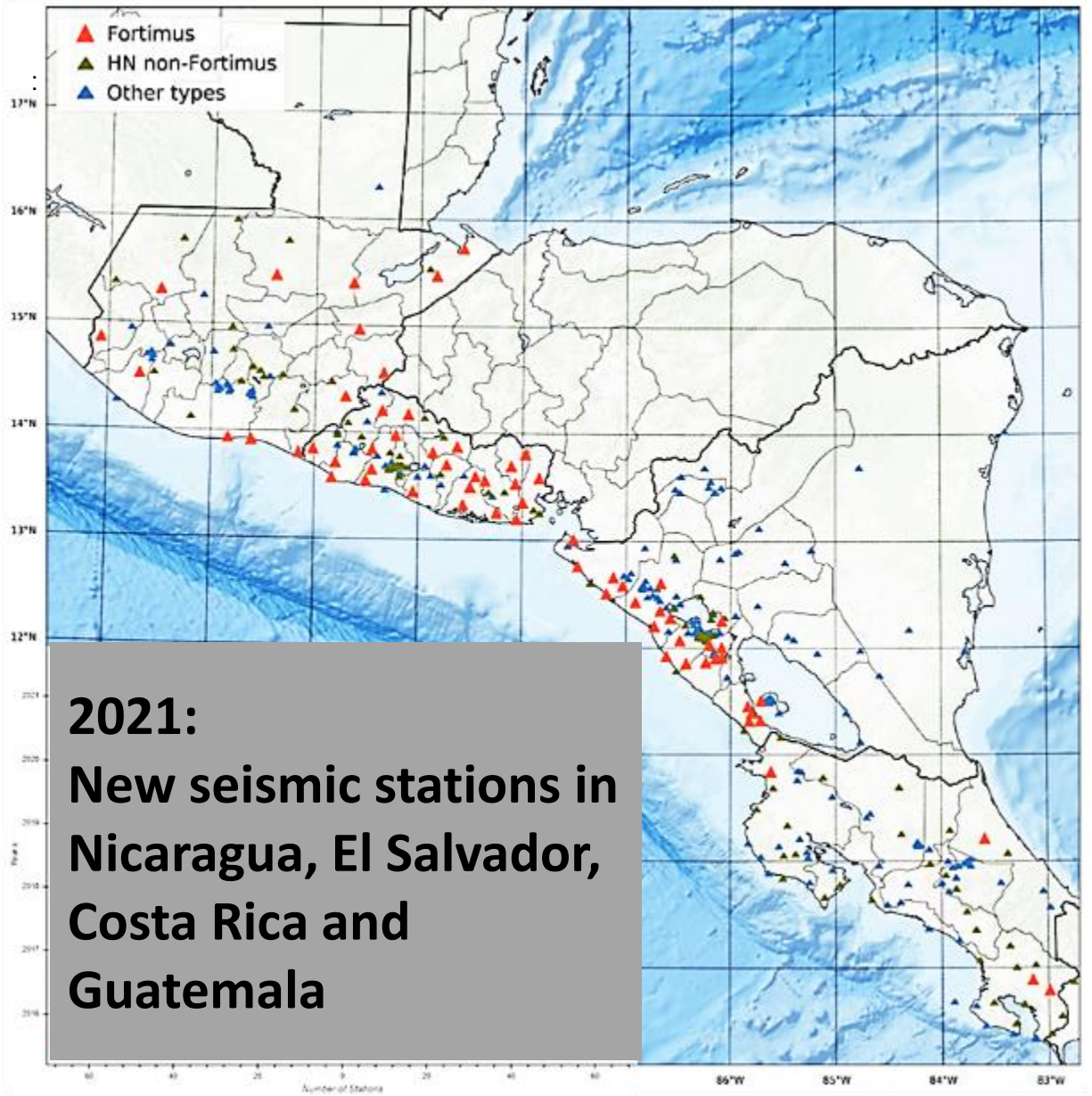
Additionally stations from the global seismic network are used

Expansion of seismic networks for earthquake and tsunami warning

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

ETH zürich



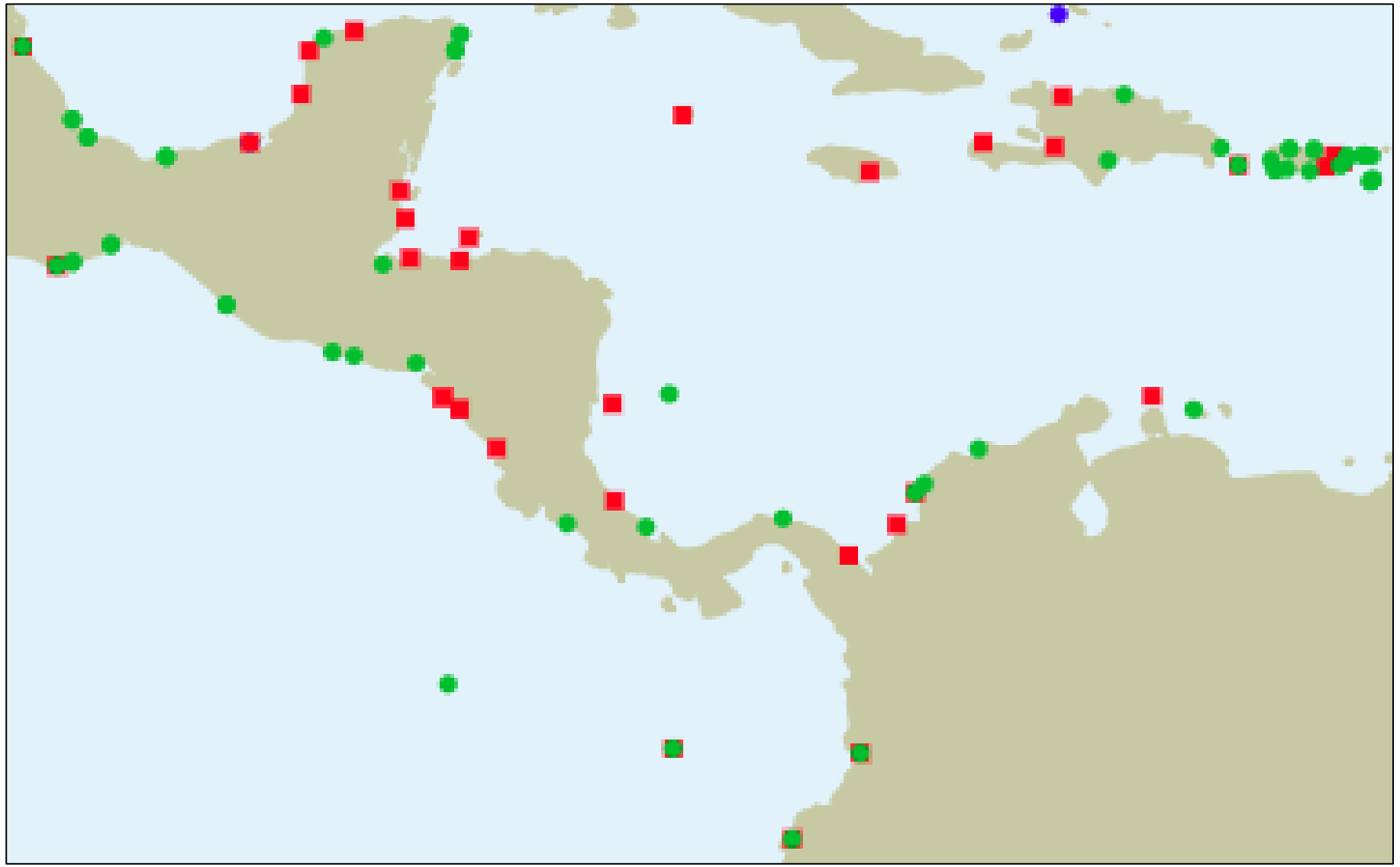
2021:
New seismic stations in Nicaragua, El Salvador, Costa Rica and Guatemala

New accelerographs
digital Fortimus installed, in cooperation with:

- Nicaragua (25)
- El Salvador (25),
- Guatemala (17),
- Costa Rica (4)

- **Reduction of the detection and localization time of earthquakes,**
- Improved quality of results,
- Possibility to calculate very fast Moment Tensor (and magnitude Mw) of strong earthquakes with local stations (not saturated).
- Creation of Shakemaps (Shakemaps)
- Seismic impact recording in major installations

Tide stations used by CATAC



- Tide stations are the weakest point of the tsunami warning system for Central America.
- The number is very low and many do not function properly.

Occurrence of slow earthquakes in Central America

In Central America there are 2 known occurrences of slow earthquakes:

- 1992 disastrous tsunami (10 m) from Nicaragua and
- 2012 tsunami affecting El Salvador and Nicaragua (5m)

Slow earthquakes have very weak seismic shaking and the magnitudes calculated with conventional methods are 1 to 2 magnitude units lower than what would correspond to their potential tsunami generation.

Thus, seismology and tsunami warning agencies may at least initially err in assigning the hazard to an earthquake.

The possibility of slow tsunamis imposes on CATAC the need to use very fast methods to determine the true Mw magnitude. For this purpose, the SCMTV module is used interactively and SCAUTOMT automatically. It is possible to obtain Mw within 5 to 7 minutes. The epicentral distance of the stations is limited to 1000 km and acekerographic stations are allowed to be used for the calculation.

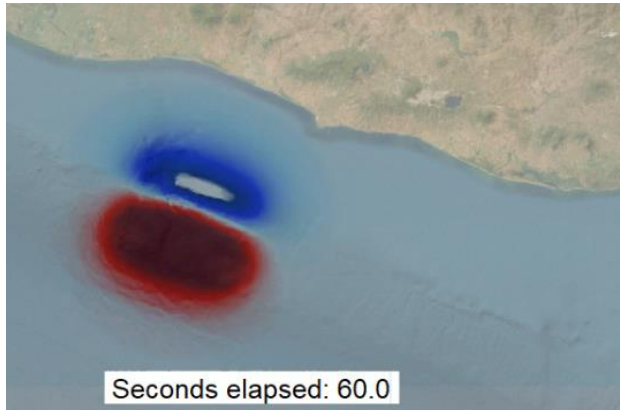
The second CATAC exercise was dedicated to slow earthquakes in order to raise awareness of this issue in Central American countries.

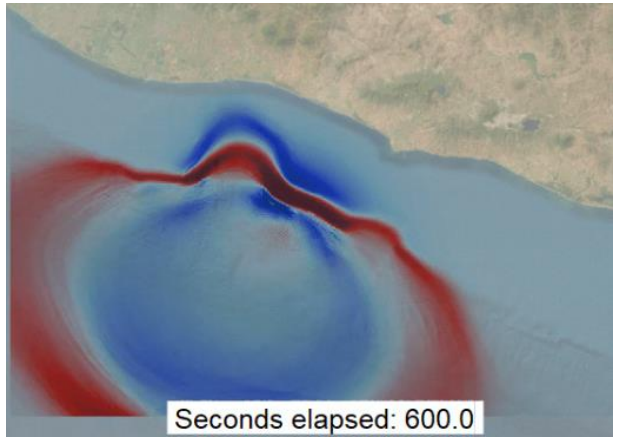
Identification of coastal areas with a reduced time of possible first impact by local tsunamis

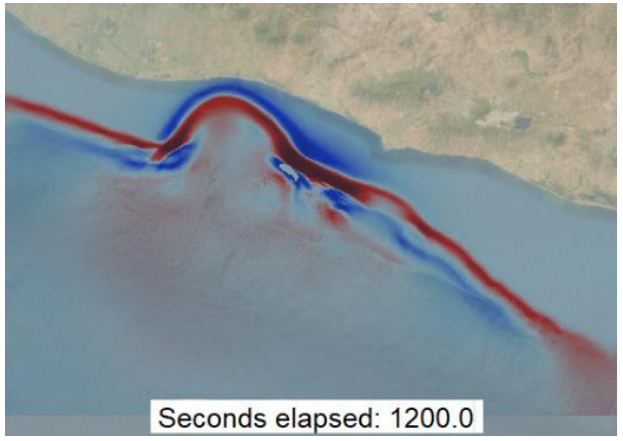
Causes:
1) The source is very close to the coast (Islands to the N of Honduras; San Juan del Norte in Nicaragua, El Limon in Costa Rica, Panama Canal).
2) Between the coast and the source zone there are very deep waters (Gulf of Chiriqui in Panama).
4)A deep sea channel that connects the source with the coast (South of Guatemala).

The existence of these zones imposes on CATAC and Civil Protection agencies the urgency to work very fast.Therefore, CATAC uses earthquake early warning methods and delivers first solutions within 2 minutes.

Example: Pacific/Guatemala-El Salvador







Example: Immediate tsunami impact, M7.3, N Honduras, 28/05/2009

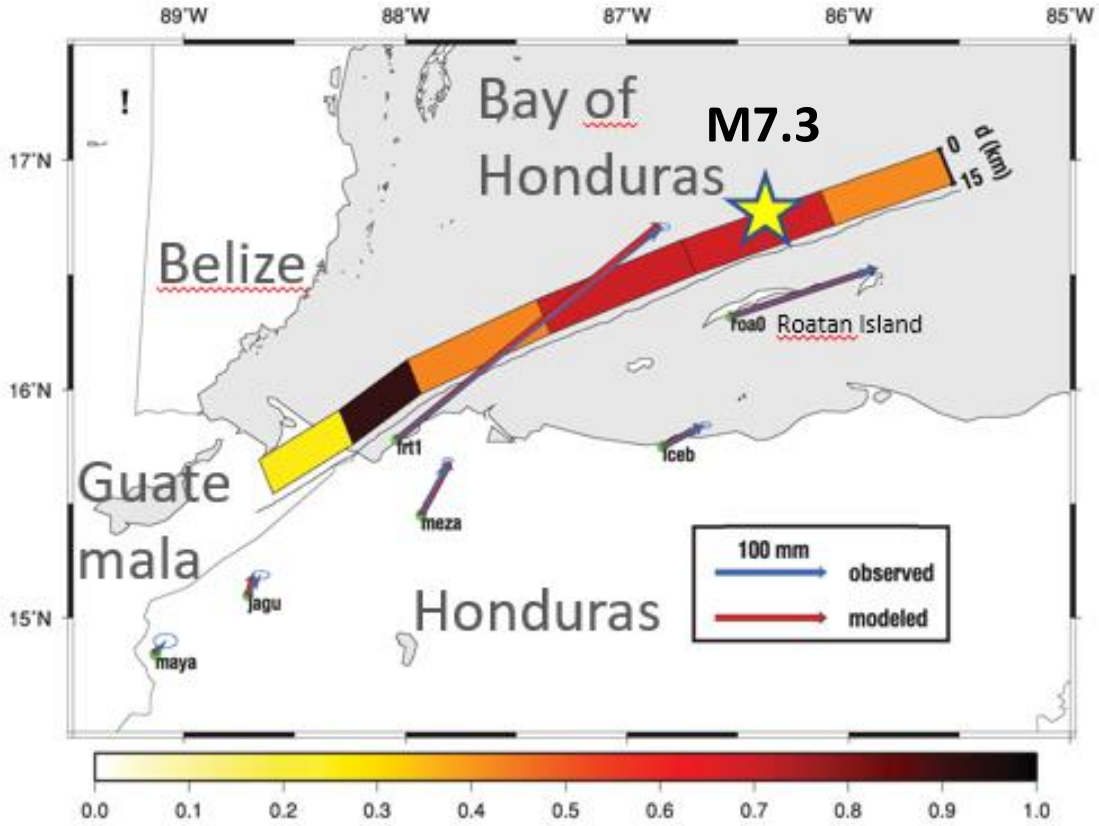
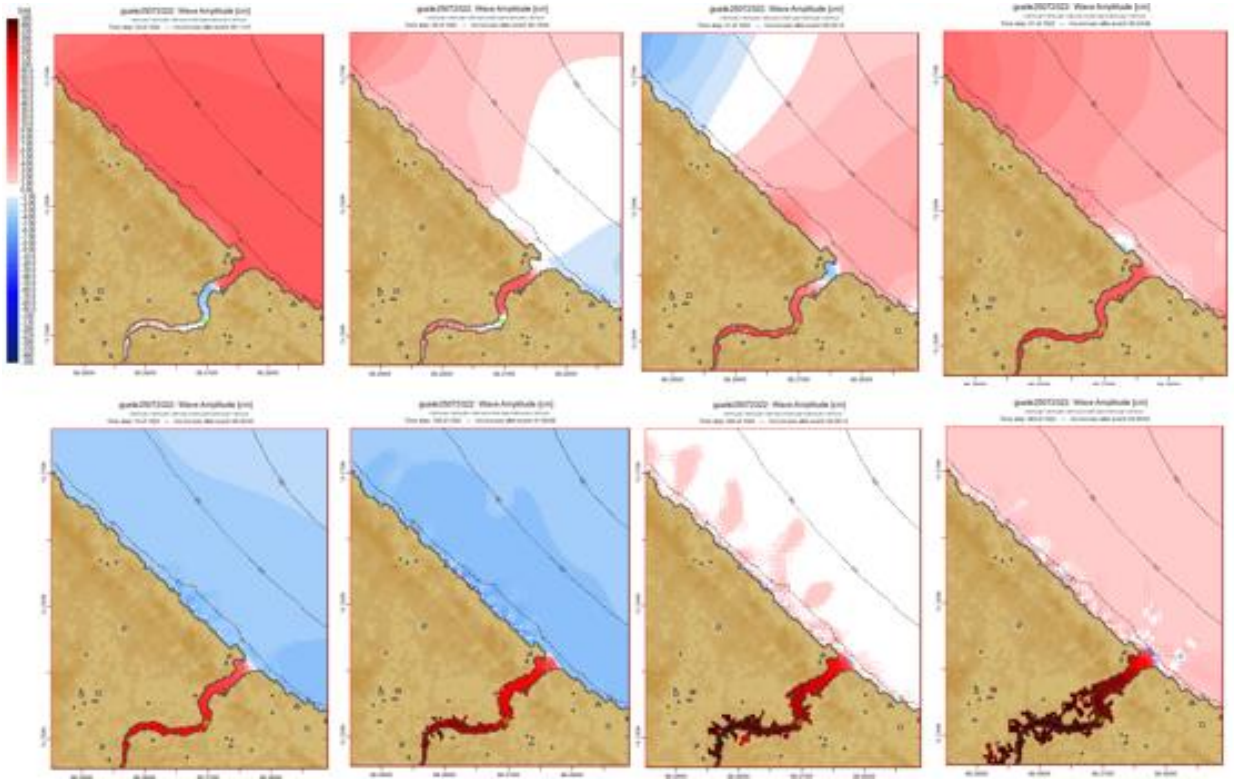


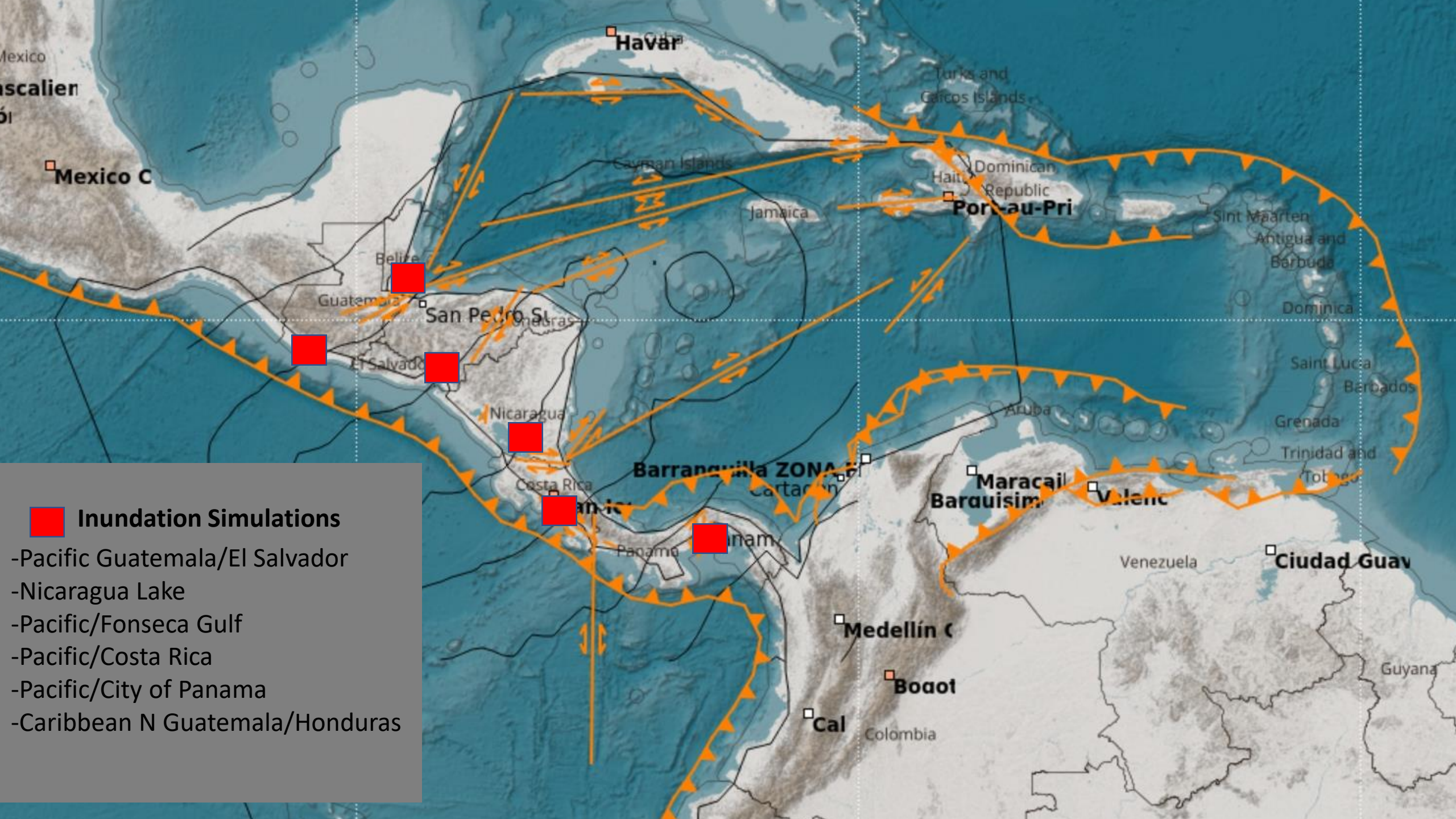
Figure 1. Slip distribution along the fault, yellow star denotes NEIC epicenter. Adapted from Graham et al. 2012. Arrows are GPS vectors post earthquake.



Series of water levels on the N Guatemalan coast and River Motagua, obtained in the simulation

The epicenter is at a distance of about 200 km from the fault segment with the máximum displacement and from the tsunami and river inundation occurrence.

N. Acosta, A. Cabrera, G. Argüello, W. Strauch (2022)Simulation of the Local Tsunami in the North Coast of Guatemala due to the Mw7.3 Earthquake, May 28, 2009, North of Honduras, LACSC, 2023


Havar
Mexico C
Cayman Islands
Jamaica
Haiti
Dominican Republic
Turks and Caicos Islands
Sint Maarten
Antigua and Barbuda
Dominica
Saint Lucia
Barbados
Grenada
Trinidad and Tobago
Aruba
Belize
Guatemala
San Pedro Sl
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Barranquilla ZONA
Cartagena
Maracaibo
Venezuela
Ciudad Guay
Medellín
Bogot
Cal
Colombia
Guyana
Inundation Simulations
-Pacific Guatemala/El Salvador
-Nicaragua Lake
-Pacific/Fonseca Gulf
-Pacific/Costa Rica
-Pacific/City of Panama
-Caribbean N Guatemala/Honduras

Acceleration of Processing

Acceleration of automatic and manual Moment Tensor calculation

-Use of data from near accelerographic stations.

-Limiting the distance of stations to be used for the first message.

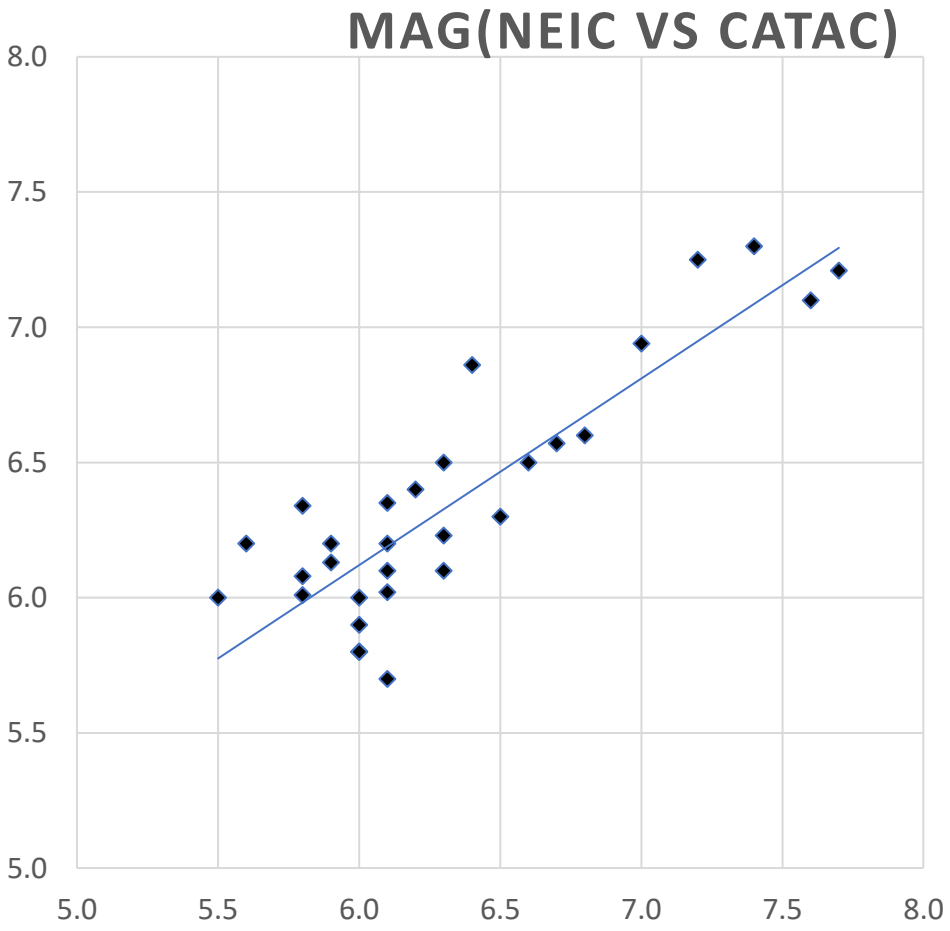
First solutions in less than 10 mins

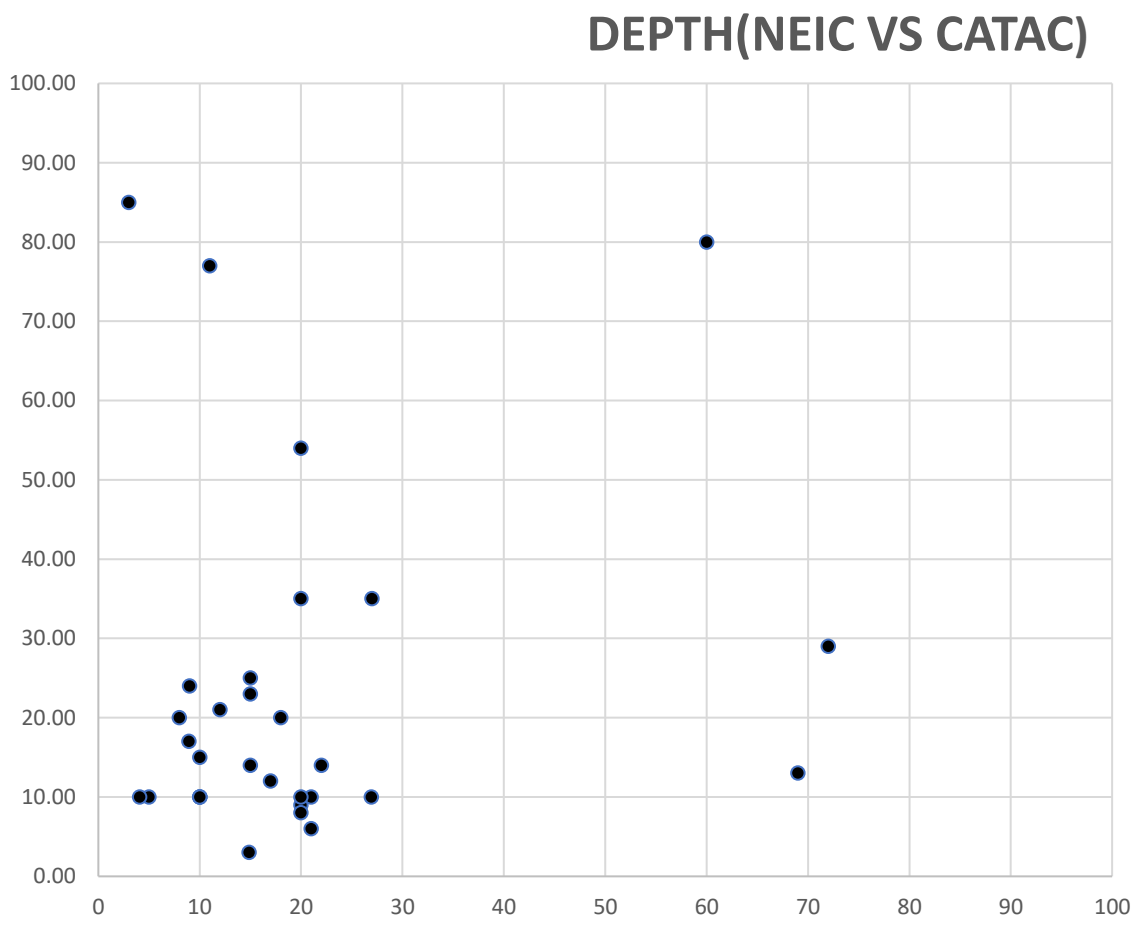
Improvements of Processing

2. Optimization of the configuration of tsunami simulations in the SeisComP module TOAST. GPU based calculations in several steps

Execution time for simulación with TOAST (easywave) GPU				
	Hours of tsunami propagation			
Bathym. arcsec	**1**	**2**	**4**	**8**
15	29	92	716	1753
30	14	32	63	140
90	7	23	46	143

CATAC: processed events bigger than M6, 11/2019 - 12/2022





EWARNICA/ATTAC project, with Switzerland and CA countries. Phase 3 2022-2024

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

ETH zürich

- Products that benefit CATAC and tsunami warning in the countries of the region.

- Upgrading of the accelerometer stations installed in 2021 will benefit CATAC and the countries of the region.
- Establishment of earthquake early warning in Nicaragua, El Salvador, Costa Rica (Honduras, Panama) will benefit the tsunami warning by CATAC and the countries.
- Method of earthquake source estimation with the FINDER module would benefit the tsunami warning by CATAC and the countries.
- Development of methods to transmit warning messages massively to the general population. Can also be used for tsunami warning.

Use of EEW Algorithm - FINDER

Finite-Fault Rupture Detector, Cooperation (ETHZ, USGS, CalTech)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Swiss Seismological Service

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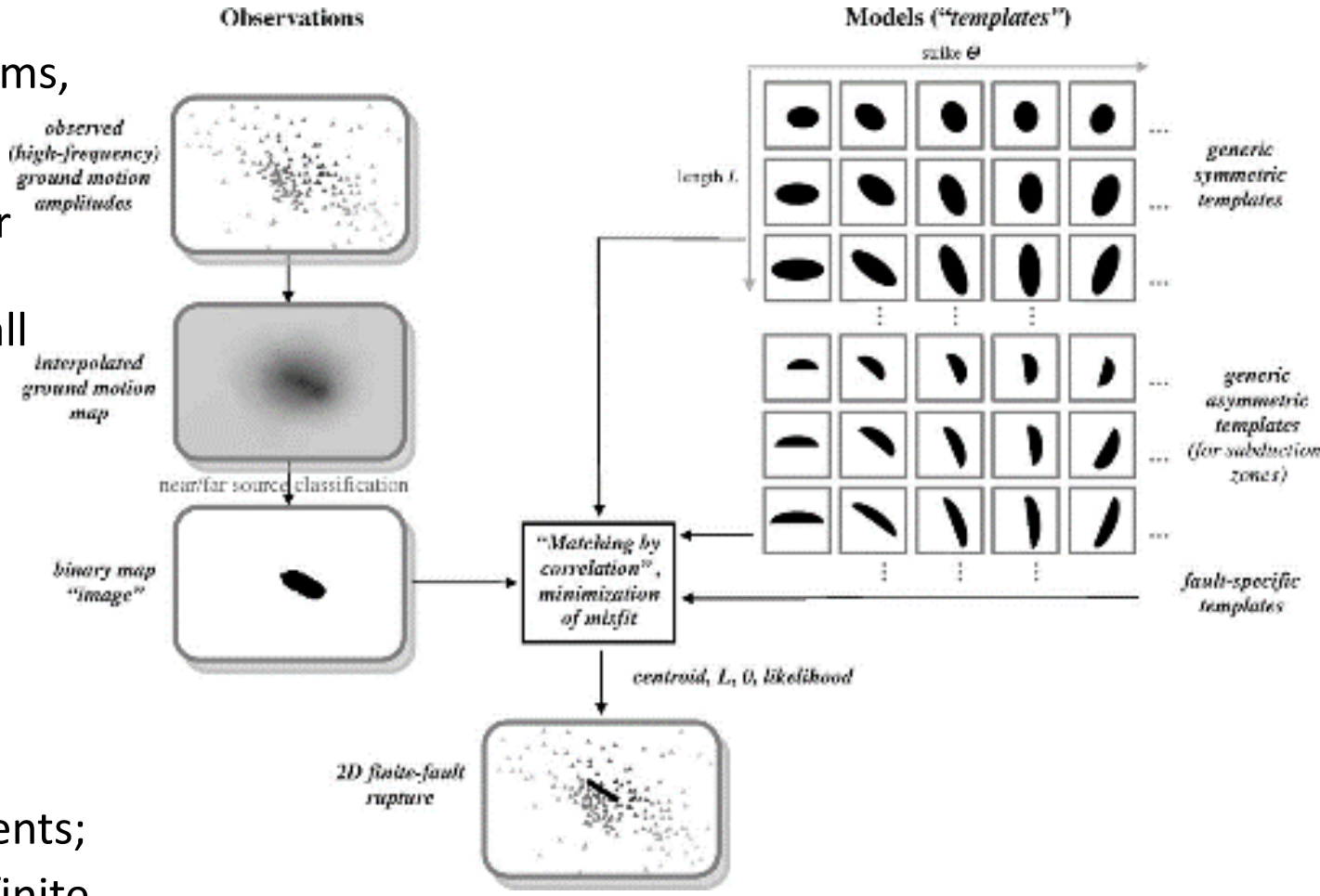
- Compared to other more traditional EEW algorithms, FinDer has a number of interesting features. (see Böse et al. (2018) for more details):
- Characterization of seismic ground motions rather than earthquake sources;
- Consistent models and uncertainties for both small and large earthquakes;
- There is no magnitude saturation in large earthquakes;
- Applicable to complex seismic sequences;
- There are no station averages, but true network solutions;
- Independent of traditional phase selection and screening partners;
- It is unlikely to be activated during teleseismic events;
- It allows the realization of seismic-geodetic joint finite fault models in real time (e.g. for tsunami warning);
- It can resolve fault plane ambiguities, including those of small earthquakes.



CATAC progress in the pilot phase of operations from 2019 to 2021.

An experimental introductory and familiarization period of about 2 years duration, 2019-2021, was conducted. During this time, only seismological messages were routinely sent. Tsunami advisory was conducted in a less formal manner via social media communications with alert recipients in the region immediately after the earthquake.

In the experimental phase, CATAC achieved the following advances:

The **24x7 shift staff was doubled,** employing 2 people per shift. Staff was trained, especially the 8 new people on the shift that INETER additionally assigned for the 24x7 service.

The **accuracy and speed** of earthquake and tsunami processing in general was improved. Experience was gained with the processing of strong earthquakes that occurred in the region: 5 earthquakes with magnitudes greater than M=7; 8 earthquakes with magnitudes between 6.5 and 7, and a large number of earthquakes with M less than 6.5.

In Central America, the greatest tsunami threat comes from local and regional sources, and areas along the Central American coasts have been identified where tsunamis can impact in less than 10 minutes after the earthquake or tsunami generator. For this reason, CATAC was dedicated to accelerate the processing of earthquakes and tsunamis. To reduce the processing time and improve the reliability of the products, a series of concrete measures were taken, which are detailed in the following.

Great densification of the seismic networks in Nicaragua, El Salvador, and Guatemala was achieved through the EWARNICA project with Switzerland, while improving the accuracy of earthquake locations. With the CATAC earthquake early warning methods, CATAC obtains a first location and magnitude of the earthquakes occurring in Central America within a few seconds after the start of the event and also accelerated the calculations of the Moment Tensor and the Mw magnitude.

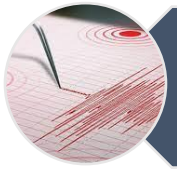
CATAC finalized the development of the **tsunami database**, which yields tsunami parameters within a few seconds after establishing earthquake parameters.

- CATAC established its **website catac.ineter.gob.ni** and continues to develop it. This site provides information on earthquakes and tsunamis for the target audience of CATAC products as well as for the general public.
- CATAC in cooperation with ETHZ/Switzerland developed **the Shakemaps website** (http://shakemapcam.ethz.ch/) of strong earthquakes recorded by CATAC that shows the impact of earthquakes which is important when assessing the situation of the coastal population after an event.
- **MARN act as a backup for CATAC:** As CATAC can be temporarily affected by adverse circumstances and lose its ability to work partially or completely, a closer cooperation with MARN/El Salvador was developed with the objective of having MARN act as a backup for CATAC.
- CATAC started to implement the use of GPS/GNSS in the process of seismological monitoring and characterization of large earthquakes. In 2021, Nicaragua established real-time transmission of high frequency data sampling from 25 GPS/GNSS stations to CATAC, with the aim to retransmit these data to UNAVCO and to implement software that allows the data to be used routinely.

CATAC Webinar in support to CEPREDENACs III Regional Exercise – June 2023

09

Hypothesis



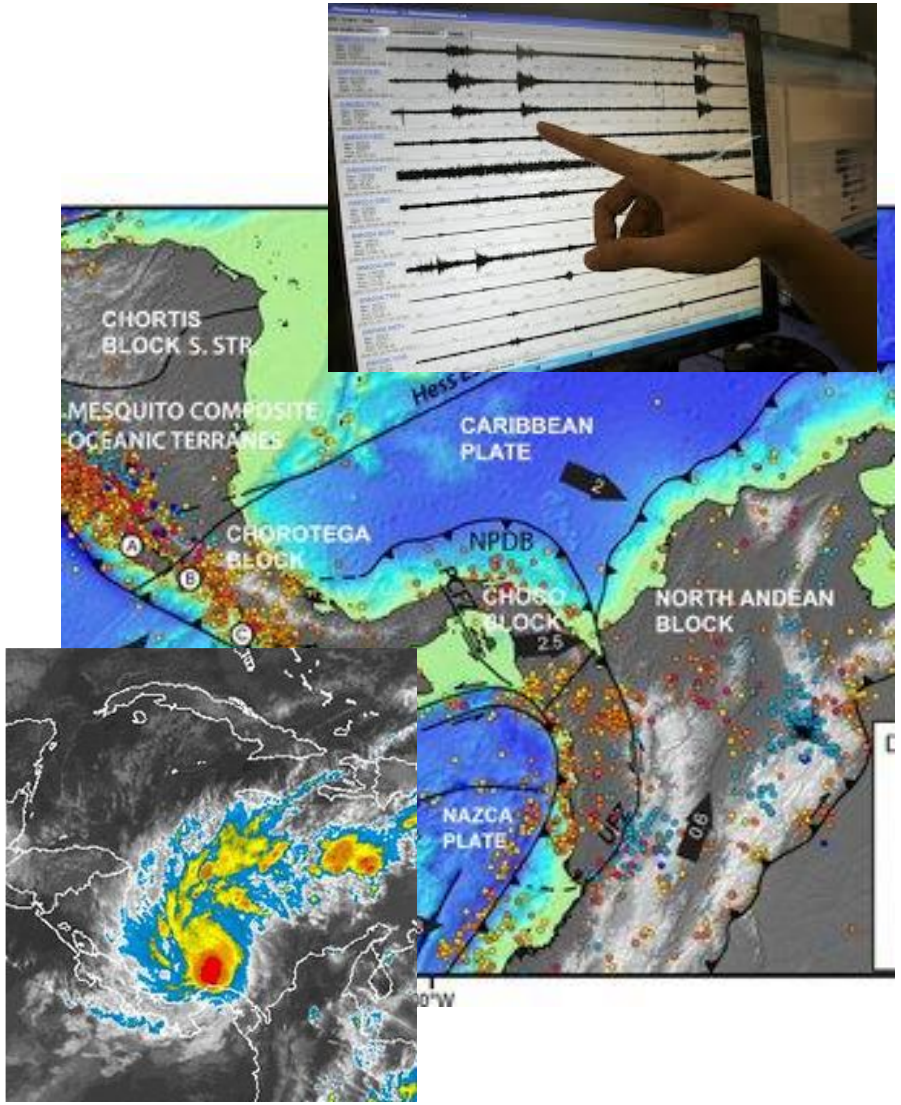
Earthquake magnitude 7.5 at a depth of 10 km, in Panama City with epicenter located in the Pedro Miguel fault, (8º58'N 79º33'W).

Damage to human settlement buildings and basic living infrastructure

trapped and missing persons, structural fires and hazardous material spills.

Passage of Tropical Wave #10 causes rivers to overflow in the provinces of Chiriqui, Bocas del Toro, Cocle and Colon causing major flooding.

Threat of Biological contamination by monkeypox



Webinar on the use of CATAC products, Feb-Mar 2023

#	Fecha y Hora	País	Institución	Tipo institución	Modalidad	Horas
1	20/2/2023 10:00	Nicaragua	SINAPRED	Protección civil	Presencial	2
2	20/2/2023 14:00		Defensa Civil	Protección civil	Presencial	2
3	21/2/2023 10:00	El Salvador	MARN	Científica	Virtual	2
4	21/2/2023 14:00		Protección Civil	Protección Civil	Virtual	2
5	22/2/2023 10:00	Guatemala	INSIVUMEH	Científica	Virtual	2
6	22/2/2023 14:00		CONRED	Protección Civil	Virtual	2
7	23/2/2023 10:00	Honduras	UNAH	Científica	Virtual	2
8	23/2/2023 14:00		COPECO	Protección Civil	Virtual	2
9	14/3/2023 10:00	Costa Rica	SINAMOT-UNA	Científica	Virtual	2
10	14/3/2023 14:00		CNE	Protección Civil	Virtual	2
11	15/3/2023 10:00	Panamá	IG-UPA	Científica	Virtual	2
12	15/3/2023 14:00		SINAPROC	Protección Civil	Virtual	2
13	16/3/2023 10:00	**República Dominicana**	Sis-USAG	Científica	Virtual	2
14	16/3/2023 14:00		Defensa Civil	Protección Civil	Virtual	2
15	17/3/2023 10:00	**Belice**	Servicio Meteo.	Científica	Virtual	2
16	17/3/2023 14:00		Protección Civil	Protección Civil	Virtual	2
17	21/3/2023 10:00		CEPREDENAC	Protección Civil	Virtual	2

prepared with CEPREDENAC, JICA

In support of 3rd regional disaster simulation, CEPREDENAC, Jun2 2023 in Panamá

15 Webinars – done.

1 final Webinars with CEPREDENAC to be organized

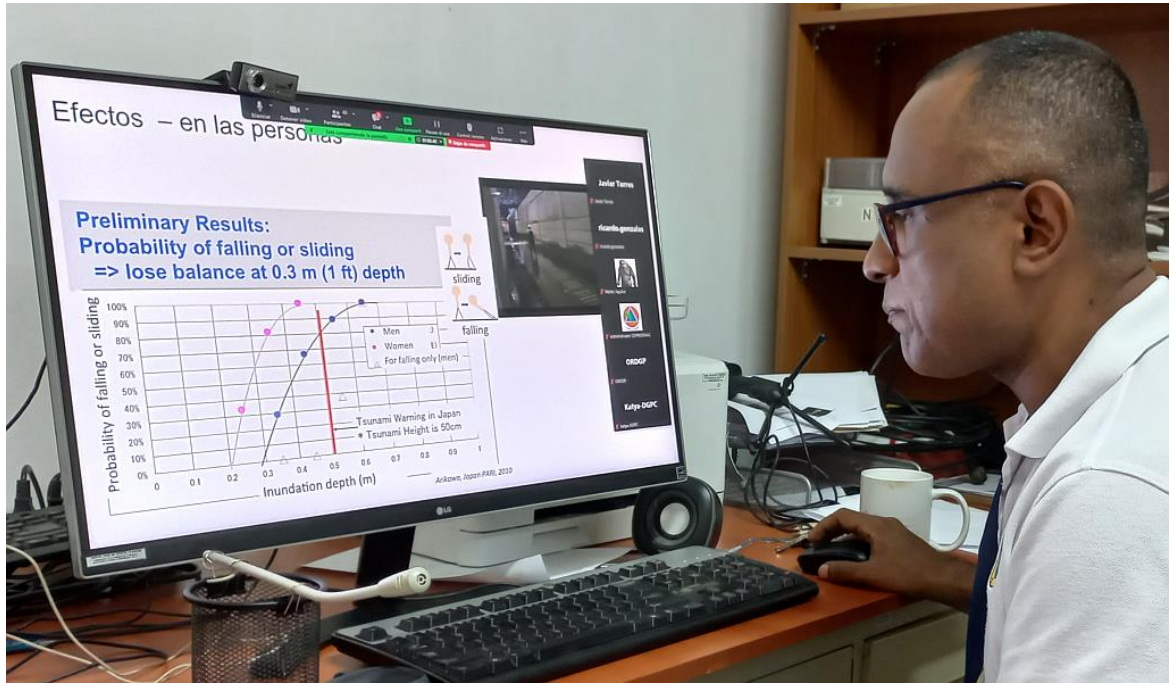
Included Belize and Dominikan Republik on request of CEPREDENAC.

During the simulation, in June 2023, meetings to be organized with Panamanian institutions to advise Panama on CATAC's performance in rapid earthquake and tsunami processing, CATAC's products and how Panama can benefit from its services.

Webinar topics

- 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

Webinar with Insivumeh/Guatemala



Norwin Acosta, CATAC, explains mínimum dangerous tsunami height

Updating the contact list of CATAC (PTWC)

National Tsunami Warning Center (NTWC), Tsunami National Contacts (TNC) and Tsunami Warning Focal Points (TWFP), according IOC webpage

- Often not updated
- Often only one institution is represented (scientific)
- Few contacts

In the discussion the interest was expressed to inlcude more persons and more institutions

Preiminary results of Webinar

- **Update contact list** of CATAC (and PTWC) messages
- **More contacts** in the countries
- **Use of social networks** for distribution of messages
- **Revision of SOP** in the countries to make adecuate use of CATAC products

New Project for Regional Capacitation at CATAC 2023-26

- Support by JICA
- Each November: **Presential capacitation** at INETER/Managua with CATAC users
- **Several Zoom** meetings each year with user institutions
- **Visits** to the institutions in the countries
- Funding of **software licences** SeisComP 5
- Funding of **equipment for capacitation**

Cooperation CATAC-MARN El Salvador

- Idea: MARN acting as backup center of CATAC
- 2022-23 several Zoom meetings
- Development of MARN´s capacity to act as CATAC backup for the next years

Planned actions 2023-24

Apr Start of new JICA project

May - Start of follow up of the Webinar, revision of protocols

May - Adaptation of CATAC Procedures according duscussions at Webinar and WG-CA

May - Correction of Message formats

Jun - 12-18, in Panamá: Regional Exercise; Capacitation for institutions in Panama

Jul - draft NEW User´s Guido CATAC

Sep - ICG/PTWS - presentation of new Users Guide

Nov - Capacitation – Zoom and in person, at CATAC/Managua,
for all countries receiving our product

Exercises

1. March 2023 CARIBEWAVE
2. June 2023 Regional EQ 7.5 exercise in Panama organized by CEPREDENAC
3. Sep-Nov 2023 PACWAVE 2023

Cooperation with MARN/El Salvador

CATAC has discussed with JICA and MARN/El Salvador the possibilities of closer cooperation between CATAC and MARN for:

- Establish Seismology/MARN as a back-up to CATAC
- Direct use of CATAC products (scimport)
- Cooperate in the development of acceleration models, layers of
- others

Funding from Nicaraguan Government for CATAC

INETER is preparing a project proposal to the Nic Government

Funding for CATAC data center 2024-2026

- Software licences
- IT hardware (workstations, servers, comm equipment)

Supported by the decision of the ICG/PTWS-WG-CA in its session from Apr 24, 2024,

CATAC proposes to ICG/PTWS XVI:

- To admin the start of CATAC's full functionality in an interim manner, starting in June 2023. *(as already decided 12/2021 by ICG/PTWS XXX for the Pacific coast of Central America)*
- To note that CATAC develops a new versión of its Users Guide corresponding to the full functionality; *taking into account the new processing methods, messaging formats and channels.*
- To take note that CATAC will present the new User´s Guide to WG-CA and ICG/PTWS XXXI in Sep 2023, for decisión, for the Pacific coast of CA.
- To program a revision of the new users guide in a session of the Steering Committee ICG/CARIBE EWS after september 2023.
- To decide on the users guide and the routine full operation of CATAC in the next session of ICG/CARIBE EWS XVII in April (?) 2024.
- enabling the final admission of CATAC by the IOC General Assembly in June, 2024.