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(of UNESCO)

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(ICG/CARIBE EWS-XVI)
25-28 April 2023

Agenda Item 4.2

Working Group 2 Hazard Assessment Progress Report

This document presents the recommendations, conclusions and a proposed work plan of Working Group 2 "Hazard Assessment". The ICG is requested to consider, comment and eventually endorse the recommendations issued by Working Group 2.

Introduction, Summary, Considerations

The Working Group 2 (WG2) on Tsunami Hazard Assessment is one of four main working groups within the ICG/CARIBE-EWS. Its primary objective is to advise the ICG on the identification and characterization of coastal hazards, their assessment and the required modeling. Among the functions of this working group is to assist the ICG/CARIBE-EWS Member States on assessing their tsunami threat.

A. Summary of Activities during the intersessional period 2021-2023

During the intersessional period 2021-2023 the following activities were held within Working Group 2 (WG2) framework:

1. Non-seismic sources

At the ICG/CARIBE-EWS-XV, WG2 received the following recommendation:
"*Recommends exploring ways to provide access to and/or compile non-seismic sources in CATSAM or another format, Provide access to and/or compile non-seismic sources*"

In response to *Recommendations from ICG/CARIBE-EWS XV*

- A published Kick'em Jenny landslide scenario (Harbitz et al., 2012). was added to CATSAM map viewer.
- Decisions made by WG2 on process for selecting scenarios:
    - The initial focus is to be on publications/reports that include numerical simulations. However, identifying sources that need to be simulated would benefit a future gap analysis.
    - Public reports sponsored by national agencies should be considered equal to peer-reviewed publications as they undergo significant expert review.
    - Other scenarios - unpublished work, master report, etc. can be considered after acceptance by the WG2.
    - It is the work of the WG2 to propose scenarios that were discussed during expert meetings, but not to run the simulations.
    - Both local and regional scenarios should be considered.
    - Need to identify individuals with expertise outside of WG2. Perhaps making a recommendation at the next ICG for other WGs and Member States to provide experts willing to contribute time/resources.
- Current state:
    - WG2 has identified 35 modeled scenarios for possible use; and 15 scenarios for future modeling

WG2 decided that for the next intersessional period, organizing an Experts Meeting on "Non-seismic Sources of tsunamis for the Caribbean" should be a top priority. (*see Section C*) This proposed activity would be a critical step to characterizing and prioritizing non-seismic tsunami sources that could impact the region. According to the NCEI/WDS Global Historical Tsunami Database, volcano and landslide generated tsunamis account for approximately 14% of all confirmed historical tsunamis observed in the Caribbean and Adjacent Regions.

2. Caribbean and Adjacent Regions Tsunami Sources and Models (CATSAM) webmap

The CATSAM (Caribbean and Adjacent Regions Tsunami Sources and Models) webmap has been publicly available since of May 2018.

The CATSAM map viewer was developed to help identify potential tsunami sources. CATSAM is intended to provide modelers and hazard assessment professionals with an understanding of the UNESCO/IOC led tsunami modeling efforts, as well as how those efforts overlap with the NOAA National Centers for Environmental Information (NCEI) and colocated World Data Service (WDS) for Geophysics Global Historical Tsunami Database.

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The following enhancements have been made to CATSAM in the intersessional period:

- Over 35 scenarios and their associated fault planes and sources have been added to CATSAM.
    - The majority of the new scenarios come from the Experts Meetings: Sources of tsunamis for the Lesser Antilles, held in Martinique from the 18th to the 20th of March 2019.
    - A landslide of Kick'em Jenny volcano scenario, as presented in Harbitz et al. (2012, Continental Shelf Research), has been added.
    - Caribe Wave 22 scenario (North Panama Deformed Belt) was added.
    - The Western Muertos Trough scenario was updated.
- Challenges in displaying IOC tide gauge stations, previously retrieved from a server-side "proxy" running at NCEI/WDS. This approach required frequent restarts to display stations. Now a “Cron Job” (i.e., scheduled commands or tasks) has been setup that grabs the station list from https://www.ioc-sealevelmonitoring.org/service.php?query=stationlist and writes it to a file locally at NCEI/WDS.
- Tsunami Ready layer removed at the request of ITIC as a Tsunami Ready interactive map is under development, as well as data not being up to date.
- Bug fixes.

Special thanks to Jorge Macías (Universidad de Malaga, Spain), Alberto López (Universidad de Puerto Rico, USA) and Carl Harbitz (Norwegian Geotechnical Institute) for their significant contributions.

It should be noted that the new URL for CATSAM is: https://www.ncei.noaa.gov/maps/CATSAM/

3. Elevation Data

3.1 Elevation data sharing

At the ICG/CARIBE-EWS-XV, WG2 received the following recommendation:

“*Recommends WG2 develop a “roadmap”, or general guidance, on how to upload elevation data to the Caribbean Marine Atlas (CMA), and encourages Member States to upload in CMA their elevation data, and to provide status of available data (e.g., extent, resolution, access, etc.) to WG2*”

In response to the Recommendation from ICG/CARIBE-EWS XV, WG2 developed a guide on uploading elevation data to Caribbean Marine Atlas. The Working Document has been shared to WG2 members and on the meeting website for ICG/CARIBE-EWS XVI.

Member States encouraged to upload their data, WG2 asks them to at minimum upload details on the available data (e.g., extent, resolution, where to obtain, etc.), as this helps identify data we didn’t know existed and is available (via request not necessarily online).

3.2 DEM Training Workshop Proposal

As a result of the data sharing challenges, the development of a proposal for "Digital Elevation Model Development Training Workshop" was developed in 2020 and updated in 2022. The need for improved capabilities in the area of collecting, processing, analyzing, and modeling elevation data (topographic and bathymetric) has been well documented by UNESCO/IOC's "Workshop on Tsunami Modelling & Mitigation 2014" report, a product of the Experts Meeting Workshop on Tsunami Modeling and Mitigation held December 1-3, 2014 in Cartagena de Indias, Colombia. The DEM Workshop proposal was developed by WG2 Chair and DEM experts from NCEI/WDS. The proposal was re-submitted June 2022 to ICG/CARIBE EWS Technical Secretary, as requested. The proposal is intended to promote a sustainable approach to DEM development in the region, when data sharing is not possible.

At the ICG/ CARIBE-EWS Officer's Meeting of January/February 2023, the Technical Secretary, Mr Bernardo Aliaga, requested to fine-tune the proposed training to the CARIBE-EWS context (e.g., identify countries that would benefit, etc.). WG2 Chair and DEM experts from NCEI/WDS prepared a cursory evaluation of existing data that would benefit Member States being trained. This evaluation, provided to the Technical Secretary and as a Working Document shared to the meeting website for ICG/CARIBE-EWS XVI, illustrates the knowledge of existing data, not data availability and should not be used to exclude participation by non-listed Member States.

WG2 decided that for the next intersessional period, a Regional DEM Training should be a priority; though perhaps secondary to an Experts Meeting on "Non-seismic Sources of tsunamis for the Caribbean". (*see Section C*) A DEM training activity would support WG2 Functions:

1. Review and evaluate the required methods and data sets, including bathymetry and coastal topography for determining the coastal hazards.
2. Advise the member states on the requirements for operating the appropriate models.
3. Develop capacity building for the appropriate modelling.

3.3 ETOPO Global Relief Model

ETOPO1 had a grid resolution of about 2 km. The new ETOPO 2022 resolution will be an enhanced 15 arc-second resolution, about 0.5 km, which is four times higher than ETOPO1. The current version, ETOPO 2022, is available in Ice Surface and Bedrock versions that portray either the top layer of the ice sheets covering Greenland and Antarctica, or the bedrock below.

Notable improvements of Caribbean interest are:

- 4x higher spatial resolution (15 arc-sec compared to 1 arc-minute)
- Improved global bathymetry (mostly from GEBCO 2022)
- Improved global topography with reduced elevation bias from vegetation/buildings (mostly from FABDEM, which is a Forest And Buildings removed Copernicus DEM).

ETOPO 2022 available at https://www.ncei.noaa.gov/products/etopo-global-relief-model

4. Understand of the current state of evacuation mapping and planning process

At the ICG/CARIBE-EWS-XV, WG2 received the following recommendation:
"*Recommends re-opening the survey on tsunami evacuation mapping in the next intersessional period to obtain a better understanding of the current state of evacuation mapping and planning process in the region,*"

WG2 recognized that another survey to evaluate this could burden Member States, considering the number of existing surveys. An alternative proposal within WG2 emerged to edit and amend the National Report to include questions on evacuation mapping and signage, so that these themes are addressed on a systematic and annual basis. During this process, WG4 also indicated the overlap between these questions and questions featured in the Caribe WAVE questionnaire, again reflecting an ongoing concern of duplication. However, the National Reports and Caribe WAVE questionnaires are sometimes not answered by the same national agency. At the ICG/Caribe-EWS Officer's Meeting of June 2022, it was suggested that there may be further overlap with Key Performance Indicators (KPIs). As a result, the Task Team for KPIs may consider how to collect this information on a systematic and annual basis.

5. Tsunami Coastal Assessment Tool (TsuCAT)

A new release of the Tsunami Coastal Assessment Tool, TsuCAT 4.3, was made available January 2023, including updated exercise messaging that more closely matches PTWC operational messaging (e.g., injects and ETA ordering), and new regional seismic sources that were vetted through the IOC Seismic Experts workshop series (i.e., expert meeting in Martinique (2019, IOC-WR-291)). Additionally, improvements to security, installation, and proxy configuration were implemented. TsuCAT can be access: https://nctr.pmel.noaa.gov/TsuCAT/

6. Other Activities

Historical Tsunami Posters updated

NCEI/WDS, included in WG2 membership, and ITIC updated the Global Historical Tsunami, Significant Earthquake, and Significant Volcanic Eruption posters through 2022. As well as being general public outreach materials, the posters are used as historical references for experts and as a way to communicate to the media during an event. The posters are distributed to warning and response personnel by the ITIC and are available digitally through both NCEI/WDS and the ITIC.

Works on tsunami deposits in the Caribbean:

- Raphaël Paris, Vice-Chair of the WG2, leaded a study (Paris et al., 2021, Marine Geology) on marshes of the southern and eastern coasts of Martinique Island. Sedimentological analyses combined with tsunami simulations demonstrate that a sand unit found at Anse Meunier at 30 cm depth (1726-1813 cal. CE) likely corresponds to the CE 1755 Lisbon transatlantic tsunami. No other tsunami or hurricane event was identified on the 11 marshes investigated over a period of 3500 years.
- On-going CT-SCAM project, funded by Région AuRA, leaded by Raphaël Paris, includes a work package focused on the "Reconstruction of the paleotsunami record in the southern Antilles (Grenadines and Carriacou)" (where very few data is available).

Training course:

- Training course on Tsunami Modelling delivered by Dr. Sven Harig (Tsunami Modeling Group, Alfred Wegener Institute, Germany): new simulations for 7 localities on the eastern coasts of Cuba from probable near tsunami sources with risk assessment purposes.

B. Recommendations for ICG/CARIBE EWS

Notes the importance of the active engagement of all members in the Working Group activities,
Urges Member States to nominate members to actively engage in the Working Group.

Acknowledges the addition of over 35 scenarios to the CATSAM interface; **Appreciates** the significant contributions of WG2 members and Invited Experts, specifically from Global Tsunami Model - Norwegian Geotechnical Institute and EDANYA Group (University of Malaga).
Recognizing the efforts of NOAA/IOC International Tsunami Information Center (ITIC) to include of CATSAM scenarios in the Tsunami Coastal Assessment Tool,
Requests Caribe Wave TT to provide WG2 with the parameters, including associated files (e.g., shapefiles, geotiff, etc.) of the corresponding scenarios once they are available for future Caribe Wave exercises;
Noting the lack of specifically identified volcanic and landslide tsunami sources for the Caribbean region exists and/or is easily accessible, therefore, **Acknowledges** the need to progressively include volcanic and landslide sources and to build a dataset of scenarios for the Caribbean,
Recommends WG2 work with Technical Secretary to organize an Experts Meetings on "Non-Seismic Sources of Tsunamis for the Caribbean";
Further Noting the initial work of WG2 to provide access to and/or compile non-seismic sources;
Recommends WG2 compile and prioritize a list of non-seismic sources; **encourages** models of scenarios to be available, when possible;
Urges Member States to nominate members with modeling experience to assist to get files prepared for display on CATSAM;
Encourages the ongoing maintenance and updates to CATSAM.

Acknowledges the WG2 completion of a guide on uploading elevation data to Caribbean Marine Atlas,
Recognizing the need for adequate local bathymetric and topographic data to perform tsunami numerical modeling and obtain tsunami inundation and evacuation maps, and **Considering** the elevation data sharing challenges in the Caribbean region,
Encourages Member States to upload their elevation data, at a minimum to provide status of available data (e.g., extent, resolution, access, etc.),
Noting the release of global relief model ETOPO 2022 which includes improved global topography with reduced elevation bias from vegetation/buildings;
Further Encourages the execution of a regional training on the development of digital elevation models (DEMs) for tsunami inundation modeling; **Considering** the recent development of a DEM Training Proposal.

Recognizing the importance of understanding the current state of evacuation mapping and planning process,
Considering the ongoing work of the Task Team on Tsunami Evacuation maps,
Notes the National Reports and Caribe Wave questionnaires request evacuation mapping and signage information yet are, in some cases, filled out by different agencies, **request** Task Team on Future Goals and Performance Indicator facilitate alignment and harmonization between survey efforts to avoid overloading Member States with work and considering resource limitations.

C. Working Group Internal Work Plan/Key Proposed Activities

Prioritization of In-person Activities

Given the limited number of resources, WG2 members voted on the in-person activities to be prioritized in the next intersessional period, funding permitted. Over 50% of WG2 members participated in this prioritization process. The results show a slight majority favored an Experts Meeting on "Non-seismic Sources of Tsunamis for the Caribbean" as the top priority, and a Regional DEM Training as a second priority; while the overwhelming majority saw both activities as priorities. Section 2 and 4 of this report provides justification on the two activities considered. Results are in the table below, with only responses receiving a vote displayed:

BOTH the Experts Meeting on "Non-seismic Sources of tsunamis for the Caribbean" AND Regional DEM Training should be equally weighted priorities.	46.67%
Experts Meeting on "Non-seismic Sources of tsunamis for the Caribbean" is a TOP priority, and a Regional DEM Training is second priority.	26.67%
Regional DEM Training is a TOP priority, and an Experts Meeting on "Non-seismic Sources of tsunamis for the Caribbean" is second priority.	20.00%
Experts Meeting on "Non-seismic Sources of tsunamis for the Caribbean" is a TOP priority, and Regional DEM Training should NOT be a priority; WG2 should further evaluate other priorities.	6.67%

**Note: the WG2 Chair abstained from prioritization voting*

7. CATSAM updates and future work

Appropriate scenarios will continue to be incorporated into CATSAM. The incorporation of Caribe Wave scenarios into CATSAM continues to rely on numerical modelling work done by WG2 members, such as EDANYA Group (University of Málaga). The preference would be to use the Pacific Tsunami Warning Center (PTWC) modelling results provided in official Caribe Wave handbooks. An arrangement has not yet been established due to personnel and/or other resource challenges. In the next intersessional period, WG2 expects to continue to work with TT on Caribe Wave exercises to ensure modelling results and other associated products are available to WG2 in formats compatible with CATSAM. The EDANYA Group, as invited experts to WG2, volunteered to provide modelling results from the numerous scenarios documented in the Experts Meeting on Sources of Tsunamis in the Lesser Antilles report.

8. Historical Tsunami Posters updates

NCEI/WDS and ITIC will update the Historical Tsunami Effects in Caribbean, Central America, Mexico and Adjacent Regions poster. The posters will be distributed to warning and response personnel by the ITIC and are available digitally through both NCEI/WDS and the ITIC.

9. Non-seismic sources future work

- Provide access to and/or compile non-seismic sources:
    - WG2 compiles a (1) list of non-seismic sources already available in the literature (and including numerical simulations), (2) and a list of non-seismic literature discussed during an expert meeting in Martinique (2019, IOC-WR-291), but not yet simulated.
      To date: identified 35 modeled scenarios for possible use; and 15 scenarios for future modeling
    - Prioritize the compiled list of non-seismic sources to be displayed on CATSAM.

- Begin process of enlisting volunteers with modeling experience to assist to get files prepared for display on CATSAM.
  Including assessment of which models are appropriate (i.e., validated, benchmarked, peer-reviewed, utilized in public reports sponsored by national agencies, etc.).
- In collaboration with ICG Technical Secretary, coordinate a future Experts Meeting on Non-Seismic Sources of Tsunamis for the Caribbean.

10. Elevation data sharing future work

- Continue to share and promote existing elevation data (e.g., bathymetry, topography).
- Support any future DEM training by ensuring appropriate participants and/or agencies are made aware of the capacity building opportunity.

Members

Membership:

1. Jeffrey Simmons, Meteorological Service, Bahamas
2. Ricardo Arthur, CZMU, Barbados
3. Ing. Ronald Sánchez Escobar, DIMAR, Colombia
4. CF Leonardo Marriaga Director CIOH Pacifico DIMAR-CCCP, Colombia
5. Claudia Urbano Investigador DIMAR-CIOH, Colombia
6. Yerinelis Santos Investigador DIMAR-CIOH, Colombia
7. Fernando Afanador Investigador DIMAR-CIOH, Colombia
8. SJ Fernando Oviedo Investigador DIMAR-CCCP, Colombia
9. Monica Arcila Profesional Especializado SGC, Colombia
10. Silvia Chacón, UNA, Costa Rica
11. Marcelino Hernandez Gonzalez, Instituto de Ciencias del Mar, Cuba
12. Heriberto Antonio Fabian Espinal, ONAMET, Dominican Republic
13. Narcisse Zahibo, Université des Antilles et Guyane, France
14. Valerie Clouard, GET, Toulouse, France
15. Jean Francois Dorville, TCGNRG (Guadeloupe), UWI Mona (Jamaica)
16. Raphaël Paris, CNRS, France
17. Alberto Lopez, Universidad de Puerto Rico, Puerto Rico, USA
18. Ms. Judith Ephraim, Sustainable Development Officer, Saint Lucia
19. Frederic J.Y. Dondin, BRGM, France
20. Nicolas Arcos NOAA/NCEI, USA
21. Diego Arcas NOAA/PMEL, USA
22. Dailing Wang, PTWC, USA
23. Franck Audemard, FUNVISIS, Venezuela
24. Sirel Colón, FUNVISIS/OVMP, Venezuela
25. Carl B. Harbitz, Norwegian Geotechnical Institute ------ Invited Expert
26. Hermann Fritz, Georgia Tech, USA ---- Invited Expert
27. Jorge Macias, Universidad de Malaga, Spain ---- Invited Expert
28. Natalia Zamora, Barcelona Supercomputing Center, (Spain) ---- Invited Expert
29. Norwin Acosta, INETER, Nicaragua
30. Martha Herrera, INETER, Nicaragua
31. Albert Jones, CCCCC, Belize ---- Invited Expert

Acronyms

BRGM - Bureau de Recherches Géologiques et Minières (France)
CATSAM - Caribbean and Adjacent Regions Tsunami Sources and Models webmap
CCCCC - Caribbean Community Centre for Climate Change
CCCP - Centro de Investigaciones Oceanográficas e Hidrográficas del Pacífico (Colombia)
CIOH - Centro de Investigaciones Oceanográficas e Hidrográficas (Colombia)
CNRS - Centre National De La Recherche Scientifique (France)
CZMU- Coastal Zone Management Unit (Barbados)
DEM – Digital elevation model
DIMAR - Dirección General Marítima (Colombia)
EDANYA - Ecuaciones Diferenciales, Análisis Numérico y Aplicaciones (research group of the University of Málaga)
ETOPO - Earth TOPOgraphy
FABDEM - Forest And Buildings removed Copernicus DEM
FUNVISIS - Fundación Venezolana de Investigaciones Sismológicas (Venezuela)
GEBCO - General Bathymetric Chart of the Oceans
GET - Géosciences Environnement Toulouse
GTM-NGI - Global Tsunami Model - Norwegian Geotechnical Institute
ICG/CARIBE-EWS - Intergovernmental Coordination Group for the Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions
INETER - Instituto Nicaragüense de Estudios Territoriales (Nicaragua)
IOC - Intergovernmental Oceanographic Commission
ITIC - International Tsunami Information Center
NCEI/WDS - National Centers for Environmental Information / World Data Service (WDS) for Geophysics
NCTR - NOAA Center for Tsunami Research
NOAA - National Oceanic and Atmospheric Administration (USA)
ONAMET - Oficina Nacional de Meteorología (Dominican Republic)
OVMP - Observatoire Volcanologique de la Montagne Pelée
PMEL - NOAA Pacific Marine Environmental Laboratory
PTWC - NOAA Pacific Tsunami Warning Center
SGC - Servicio Geológico Colombiano(Colombia)
TCGNRG - The Caribbean Geophysical and Numerical Research Group
TsuCAT - Tsunami Coastal Assessment Tool
TT - Task Team
UNA - Universidad Nacional de Costa Rica (Costa Rica)
UNESCO - United Nations Educational, Scientific and Cultural Organization
UWI - The University of the West Indies
WG – Working Group