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130

TSUNAMI WATCH OPERATIONS

Global Service Definition Document

UNESCO

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This Global Service Definition Document (GSDD) describes global tsunami warning services that are provided by regional tsunami warning systems operating in different ocean basins as a global system of systems and coordinated by the Intergovernmental Oceanographic Commission.

It is an official document of the Intergovernmental Oceanographic Commission (IOC). Changes to this document can only be authorized by the TOWS-WG or by its Inter-ICG Task Team on Tsunami Watch Operations.

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Report prepared by the Task Team on Tsunami Watch Operations established by the Working Group on Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems (IOC/TOWS-WG)

The IOC publication *Tsunami Glossary, 2016* (IOC Technical Series, 85; IOC/2008/TS/85 rev.2) is useful complement to the GSDD

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CONTENT

ANNEXES

1. INTRODUCTION

Through Resolution XXIV-14, the IOC Assembly at its 24th session decided on the establishment of a Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG), tasked primarily to advise the IOC Governing Bodies on coordinated development and implementation activities on warning and mitigation systems for tsunamis and other hazards related to sea level of common priority to all Intergovernmental Coordination Group on Tsunami Warning and Mitigation Systems (ICG/TWSs). The Assembly adopted Resolution XXV-13 at its 25th Session in 2009, which established an Inter-ICG Task Team on Tsunami Watch Operations which has since been working towards working towards harmonization of methods and standards for issuance of tsunami advisories, advice on modalities of operation and develop guidelines for the requirements of Regional Warning Systems. This Task Team has already come up with several important recommendations to this effect. The TOWS-WG during its seventh meeting held at Paris in February 2014 actioned the Task Team to develop a Global Tsunami Service Definition Document based on agreed concepts and guidelines and informed by the Task Team report to TOWS-WG-IV. Accordingly, this document describes global tsunami warning services that are provided by regional tsunami warning systems operating in different ocean basins as a global system of systems and coordinated by the Intergovernmental Oceanographic Commission.

2. SYSTEM ARCHITECTURE OF THE GLOBAL TSUNAMI WARNING SYSTEM

Regional Tsunami Warning Systems operating in each Intergovernmental Coordination Group (viz. IOTWMS, PTWS, NEAMTWS, CARIBE-EWS) are the building blocks of a global TWS. Each Regional Tsunami Warning System ideally comprises of National Tsunami Warning Centres (NTWC) / Tsunami Warning Focal Points (TWFPs) in each country receiving tsunami forecast information from one/more Tsunami Service Providers (TSPs).

The TSPs will distribute products to NTWCs/TWFPs and to other TSPs operating within the ocean basin. Ultimately it is the NTWCs/TWFPs, operating within the legal framework of the sovereign nation in which they reside and serve, that provide warnings, watches, and advisories to their citizens, public and private agencies. These warnings are based either on the NTWC’s own analysis of the situation, or on the forecast information received from TSPs, or on a combination of all.

The TSPs operating within an ocean basin should be interoperable not only within themselves but also with other ocean basin TSPs, by using common and agreed formats for information exchange, address service requirements, follow agreed, high-level operating Standard Operating Procedures (SOPs), share information on procedures and processes. Proper backup should be built into the TSP services for each region to cater to any unplanned failures so that the region receives tsunami forecast information from one source or the other. The global TWS therefore operates as a “system-of-systems”.

3. AREA OF RESPONSIBILITY OF THE ICGS

The Area of Responsibility (AoR) of each regional tsunami warning system and the Area of Service (AoS) of Tsunami Service Providers (TSPs) operating within a regional tsunami warning system should be decided by respective ICGs. While addressing the above aspects, it is to be ensured that these systems should offer coverage to the coastal regions of all IOC as well as non IOC Member States that are vulnerable to a tsunami.

The current AoR map delineating the areas of responsibility of the four ICGs and AoS covered by the ICG Tsunami Service Providers is shown in Figure 1.

4. OPERATIONAL ELEMENTS OF A REGIONAL TWS

At the heart of a regional tsunami warning system are the Tsunami Service Providers (TSPs) operating 24 hours per day, 7 days per week and NTWCs/TWFPs. A TSP should do two things as fast as possible: locate any moderate or larger sized earthquake, and assess its magnitude. Once that is accomplished, they can begin to assess any potential tsunami threat to the regions in its area of service. The first tsunami bulletin issued by a TSP is usually based on seismic information. Later bulletins follow up model-based forecasts and/or with sea level observations. The real-time sea level observations are key element as they are used to help confirm the existence of a tsunami or cancel a tsunami warning. However, for the areas which are very close to the source, the time for confirmation may not exist. In such cases, the use of numerical modelling to determine the potential run-ups and inundation from assumed local or distant tsunamis are recognized as useful and important tool. Models can be initialized with potential worst case scenarios for the tsunami sources or for the waves just offshore to determine corresponding impact on nearby coast. This information then forms the basis for creating Tsunami inundation and evacuation maps and procedures. Hence the operational elements of a TSP include seismic data analysis, sea level data analysis, tsunami modelling and forecasting, tsunami advisory preparation as well as dissemination.

4.1 TSUNAMI SERVICE PROVIDER (TSP)

A centre that monitors seismic and sea level activity and issues timely tsunami forecast information within an ICG framework to NTWCs/TWFPs and other TSPs operating within an ocean basin. The NTWCs/TWFPs may use these products to develop and issue tsunami warning for their countries. TSPs may also issue public messages for an ocean basin and act as NTWCs providing tsunami warnings for their own countries. Bi-lateral, multi-lateral and sub-regional arrangements may also exist to provide products for a subset of Member States within an ICG.

4.2 NATIONAL TSUNAMI WARNING CENTRE (NTWC)

A center officially designated by the government to monitor and issue tsunami warnings and other related statements within their country according to established national SOPs.

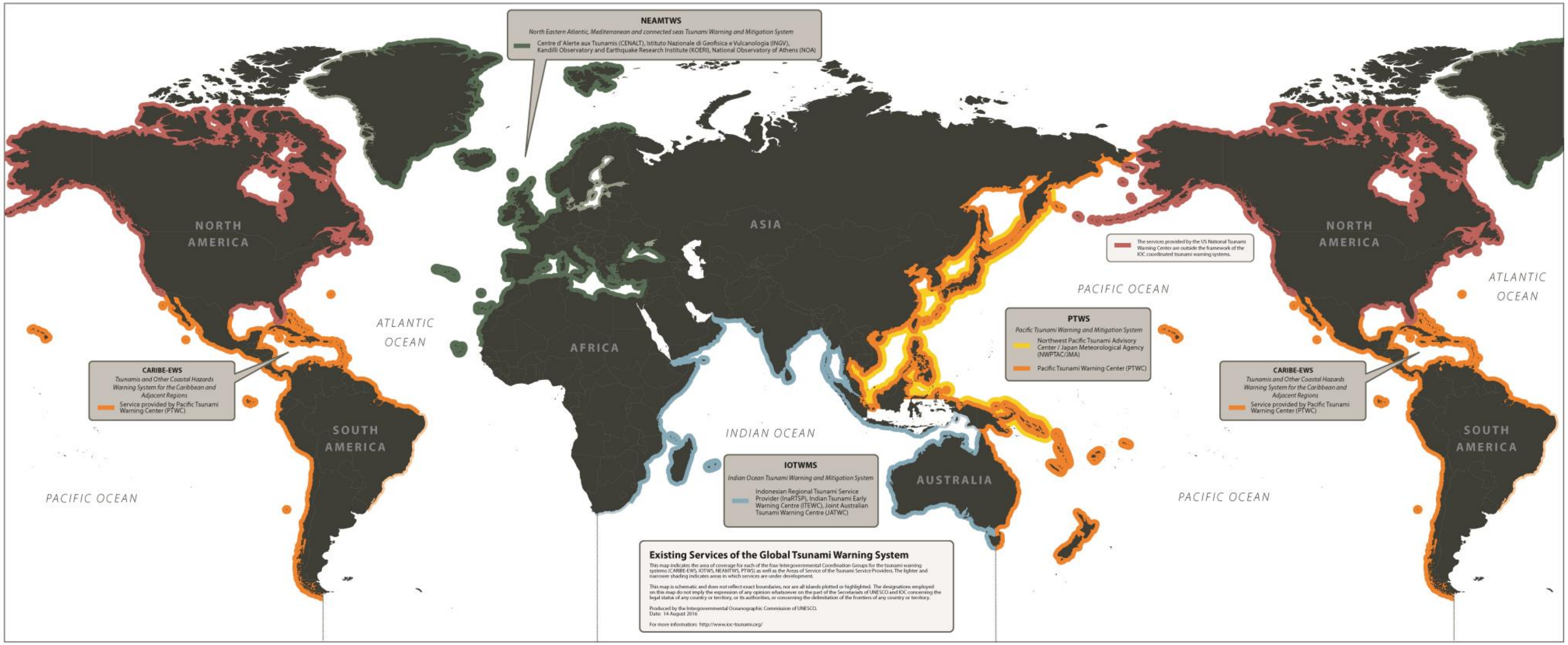
4.3 TSUNAMI WARNING FOCAL POINT (TWFP)

A 24x7 point of contact (office, operational unit or position, not a person) officially designated by the NTWC or the government to receive and disseminate tsunami information from an ICG-TSP according to established national SOPs. The TWFP may or not be the NTWC.

4.4 TSUNAMI NATIONAL CONTACT (TNC)

The person designated by a Member State to an Intergovernmental Coordination Group (ICG) to represent his/her country in the coordination of international tsunami warning and mitigation activities.

Figure 1: Global coverage of the four TWSs
(Reference: IOC/TOWS-WG-IX/3 Rev. Annex IV, page 51)



4.5 BILATERAL/MULTILATERAL/SUB-REGIONAL SYSTEM

Bilateral or multilateral arrangements can be considered to enhance the equipping of the regions with observation networks such as seismic & GNSS on land and coasts with tide gauges and tsunameters.

Through bilateral agreements, NTWCs may request TSPs to directly send TSP exchange products to them. While preparing coastal forecast points (CFPs), NTWCs may consult with and provide information to TSPs to correct CFP locations/names.

NTWCs may develop bilateral arrangements with TSPs for advice on how to utilize TSP products to determine local impacts/threats.

4.6 OBSERVATIONAL NETWORK

Effective tsunami warning depends on rapid detection and assessment of earthquakes, followed by confirmation that a tsunami has been generated and measurement of the waves.

Seismic Network:
All ICG-TSPs utilize automatic monitoring systems to assess earthquakes as they occur. When earthquakes meet certain criteria, manual analysts are alerted and begin assessing the event. For large earthquakes this usually happens within a few minutes of the initial rupture.

The seismic monitoring network used by TSPs in each regional warning systems is based on various real-time networks being operated by agencies such as IRIS Global Seismographic Network (GSN), Comprehensive Nuclear Test Ban Treaty Organization (CTBTO), the German Research Centre for Geosciences (GFZ) Geofon Extended Virtual Network and stations from other national and regional networks. A map of the network used by PTWC is shown in Figure 2.

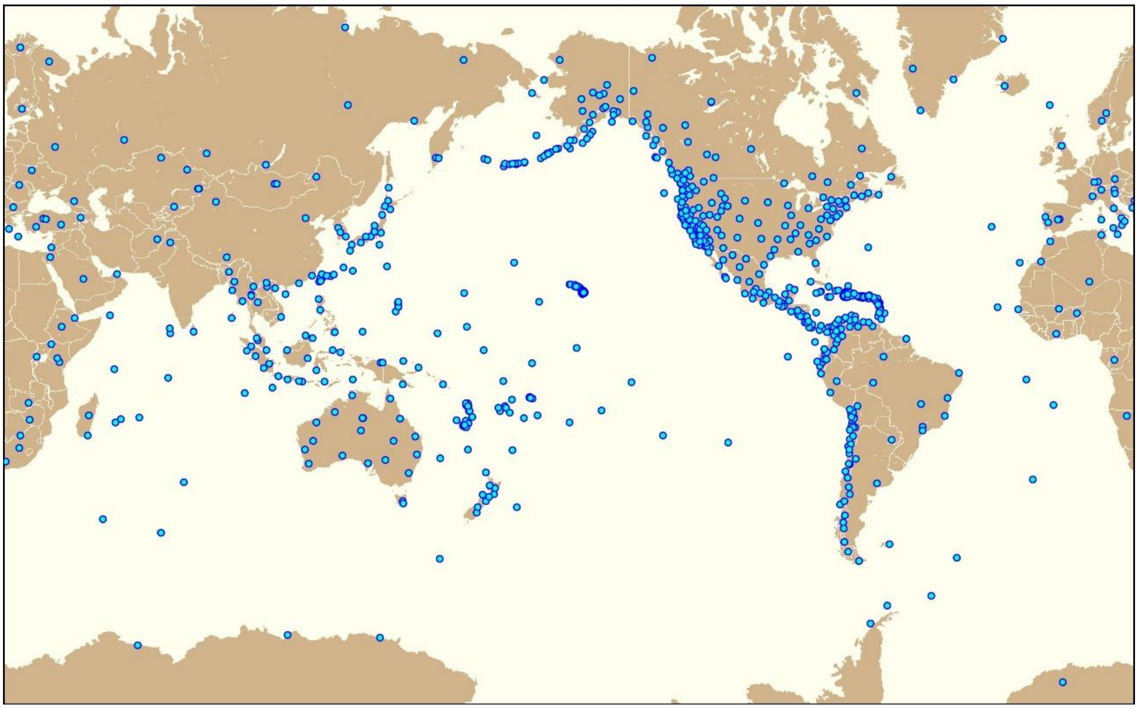


Figure 2: Network of seismic stations operated by several Member States and used by PTWC (Image Courtesy: PTWC, December 2016)

Sea Level Network:
In order to confirm whether an earthquake has triggered a tsunami, it is essential to measure the change in water level close to the fault zone and as it propagates. There are two basic types of sea level gauges: deep ocean tsunami detection buoys (commonly referred to as "tsunameters" or tsunami buoys) and coastal tide gauges. Tsunameters provide best information on open ocean tsunami wave characteristics, as the signal has not been conditioned by shallow water bathymetry. The tsunameter sea level information is therefore the most appropriate information for comparison to, or assimilation in numerical tsunami models to forecast wave heights and basin wide propagation characteristics. Coastal tide gauges can be used to verify generation of a tsunami. They provide information on the local response to a tsunami generated by a near-field or far-field source. They can also be used to monitor when the tsunami threat has passed. Tsunami buoys and coastal tide gauges are operated by a number of countries and organizations. Maps of currently available tsunami buoys and tide gauges are given in Figure 3 and Figure 4 respectively.

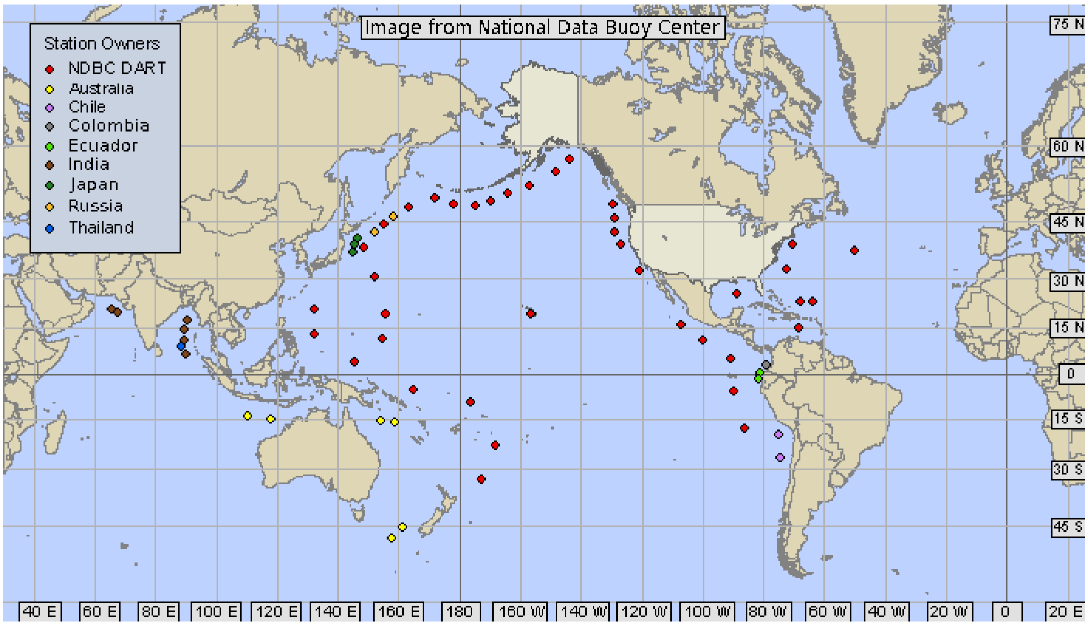


Figure 3: Network of tsunami buoys operated by several Member States (Image Courtesy: National Data Buoy Centre, April 2016)

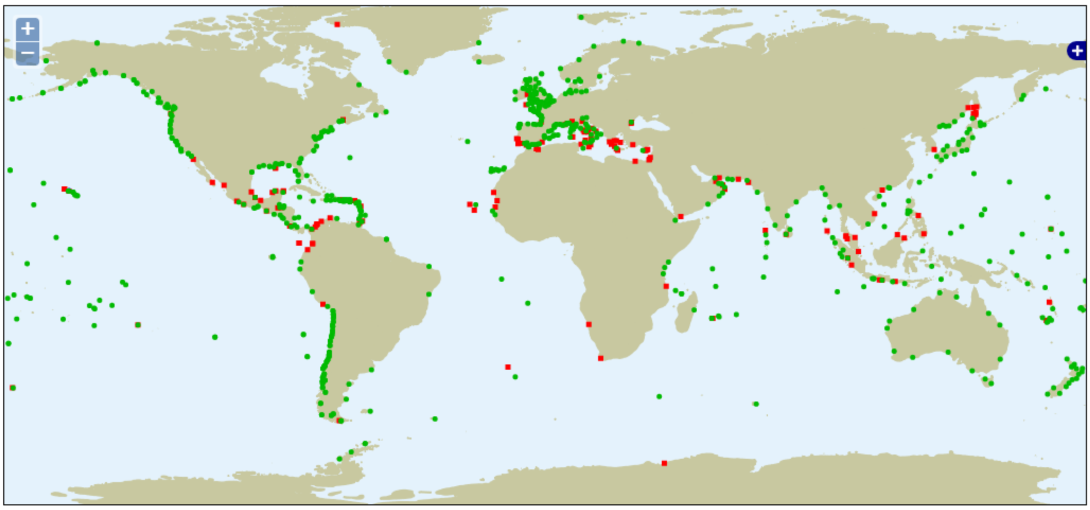


Figure 4: Network of tide gauges operated by several Member States (Image Courtesy: IOC Sea level monitoring facility, April 2016)

4.7 FORECASTING TECHNIQUES

ICG-TSPs base their forecasts of tsunami characteristics either based on earthquake magnitude (qualitative) or based on numerical oceanographic models (quantitative). The size and spread of a tsunami depends on the location, length of rupture, and the orientation and amount of vertical motion in the sea floor caused by an earthquake, and the bathymetry over which the tsunami travels towards the shore. The numerical models must therefore be initialized with these earthquake rupture parameters and include bathymetry data. Because initial tsunami bulletins must be issued within minutes of an earthquake occurrence, real-time running of the TSPs' models is not currently practical. As a result, all TSPs have carried out large numbers of non-real time model runs, using a range of possible earthquake characteristics. These scenario databases can be quickly compared to observed earthquake characteristics, so that the best match can be selected as the basis for forecasts.

4.8 STANDARD OPERATING PROCEDURES (SOPS)

To be interoperable, the TSPs need to have a common high-level SOP. However, each individual TSP needs to create more detailed SOPs to reflect their site specific operating environment. Figure 5 depicts a typical SOP being followed by the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) along with the three stages of activities, including the roles and interactions, typical input and output information between TSPs and NTWCs/TWFPs. The three stages are:

- Stage 1: Identify Threat
  - TSPs to detect an earthquake, assess its potential tsunami threat and issue bulletins to NTWCs in its AoR.
  - First Bulletin might be based on only seismic information.
- Stage 2: Threat Information Exchange and Dissemination
  - Later Bulletins follow up with model-based forecasts (EWA, ETA) and sea-level observations.
  - NTWCs/TWFPs prepare national warnings as per their SOPs and may report back to TSPs by providing Situation Reports (SitReps) including their current warning status.
- Stage 3: Update Advice
  - Updated threat levels, more sea level observations, and/or threat passed information is exchanged.

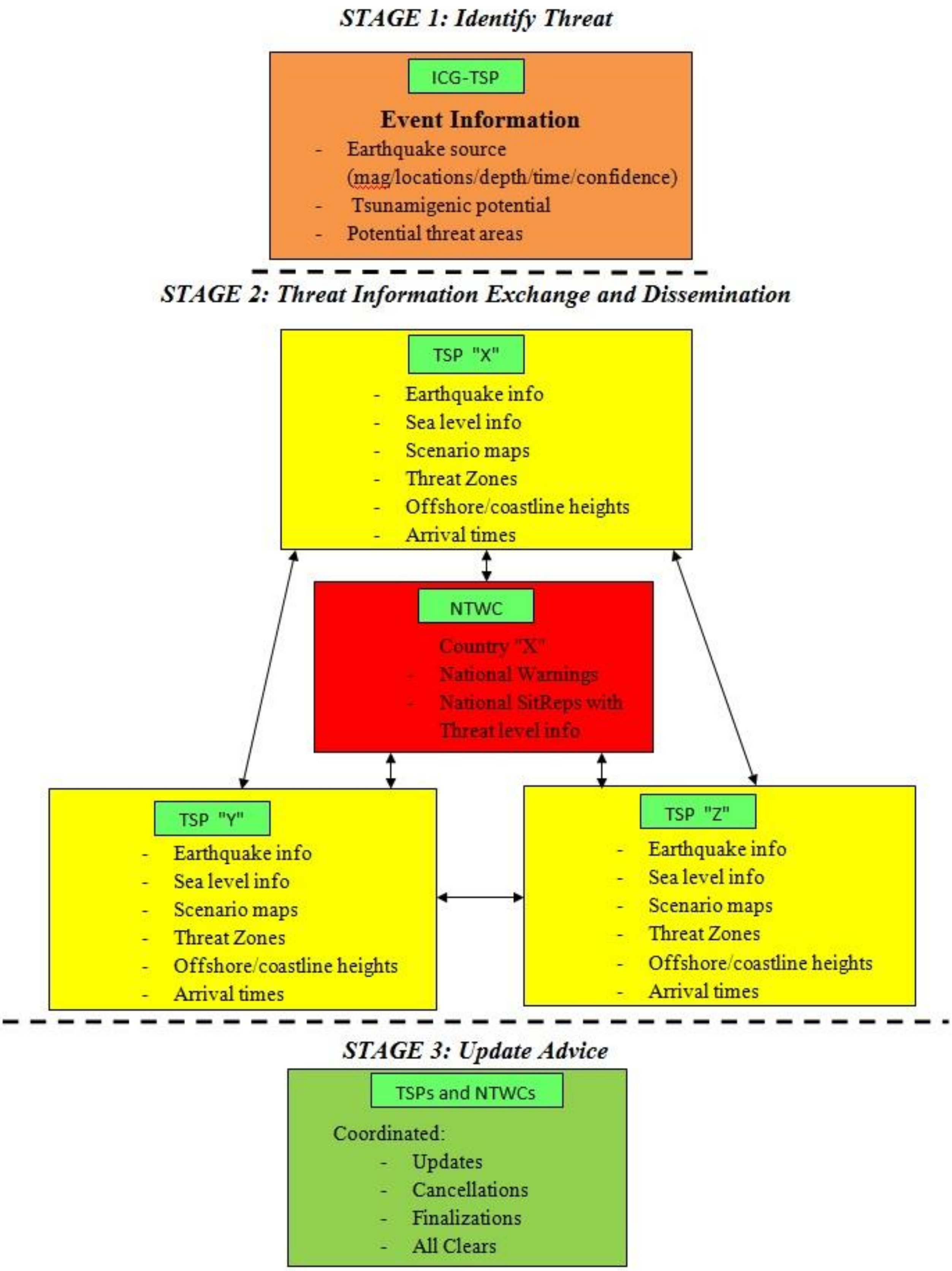


Figure 5: Typical Standard Operating Procedure (SOP) followed in the IOTWMS

5. REQUIREMENTS FOR TSPS/NTWCS/TWFPS

5.1 ROLES & RESPONSIBILITIES OF ICG-TSP:

- Determine and provide timely initial earthquake information
- Determine more specific threat information using output from scenario databases produced by tsunami models, using earthquake source information and verified by sea level information
- Provide timely tsunami forecast information for use in preparation and issuing of national tsunami warnings by NTWCs/TWFPs
- Monitor tsunami propagation and provide updated information (observed tsunami amplitude measurements) in priority
- Provide timely standardized Situation Reports (SitReps) for use by other TSPs and NTWCs, as mandated by each ICG
- Serve as a backup centre to other TSPs, if required
- Serve as an NTWC for the country in which it resides
- Participate in communications tests, tsunami exercises, maintenance of contact database in consultation with the IOC/ICGs.

5.2 ROLES & RESPONSIBILITIES OF NTWC:

Recommended roles and responsibilities of a NTWC are described below:

- Responsible for making decisions, using TSP advice of their choice, and issuing tsunami warnings as per their national SOP
- Provide timely standardized SitReps for use by other NTWCs and TSPs, including the status of their warnings, if mandated by the respective ICG
- Consult with and provide information to TSPs on CFP locations
- Work out arrangements with TSPs for advice on how to utilize TSP products to determine local impacts/threats
- Establish threat levels and develop SOPs for the corresponding jurisdictions. Utilize TSP products for initializing inundation model output/selecting inundation scenarios
- Conduct hazard mapping and risk assessments using source hazard information (e.g. historic/potential earthquakes, volcanoes) inundation models/maps and vulnerability assessment
- Provide information/warnings and work with emergency management authorities on how to determine threat zones and develop/select appropriate evacuation maps.

5.3 ROLES AND RESPONSIBILITIES OF TWFP

- Responsible to receive TSP forecast information and take necessary actions based on the national SOPs
- Provides timely updates to the contact information to IOC.

5.4 CAPABILITY REQUIREMENTS FOR ICG-TSP

In order to provide required service and undertake agreed SOPs, Regional TWS should come up with a set of capability requirements that each of the TSPs will need to demonstrate. A few important ones are listed below:

- Access to real time data sources and capability to produce standardized seismic and sea level parameters
- Appropriate historical database of earthquakes and tsunamis
- Maintain or have access to benchmark, pre-calculated numerical model scenarios
- Revise advisories in light of additional seismic and sea level data
- Provide timely and effective tsunami advisories to respective NTWCs/TWFPs
- Provide products in globally standard formats
- Disseminate tsunami forecast information freely and timely to NTWCs/TWFPs on the Global Telecommunications System (GTS) and Internet and all other possible means of communication
- Adequate trained and experienced staff, utilities, and resources to operate functionally 24 hours per day, seven days per week (24/7)
- Adequate infrastructure and back-up facilities to continue operating during power cuts and national emergencies such as all critical equipment on 30-min UPS, generator or alternative power backup (with 1 day of back-up capability), all critical equipment operating in duplicate and all critical communications circuits with backup
- Staff should be able to communicate in English.

6. ICG-TSP SERVICES

The services of a TSP commence whenever an earthquake of more than a pre-decided threshold occurs that can generate tsunamis capable of impacting the coastlines in its area of service. While the area of responsibility defines which coasts will receive tsunami forecasts from the ICG-TSPs, the fact that tsunamis can have impacts at long distances from the earthquake source means that it is also necessary to define the area in which earthquakes will be monitored and assessed. The maps delineating the Earthquake Source Zones monitored by each ICG-TSP and the thresholds for issuing bulletins are as attached in Annex I.

6.1 CARIBE-EWS-TSP

Tsunami Service Provider services in the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions commence whenever an undersea or coastal earthquake is recorded in the Caribbean and adjacent regions with a magnitude >6.0 and earthquakes in Atlantic Ocean with a magnitude >6.5. For earthquake in Pacific and Indian Ocean a forecasted wave amplitude >30 cm in CARIBE-EWS AoR will trigger issue of a bulletin.

6.2 IOTWMS-TSP

Tsunami Service Provider services in the Indian Ocean Tsunami Warning and Mitigation System for an earthquake event commence and Earthquake Bulletins are issued whenever an undersea or coastal (up to 200 km inland and regardless of depth) earthquake is recorded in the Indian Ocean, Pacific Ocean or South Atlantic source zones with a magnitude ≥6.5. These are followed up with Treat Assessment Bulletins if the earthquake is ≥6.5 and within 100 km depth in the Indian Ocean or ≥8.0 and within 100 km depth in the Pacific and South Atlantic Oceans.

6.3 NEAMTWS-TSP

Tsunami Service Providers of the Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas issue tsunami messages whenever an undersea earthquake of >5.5 is recorded in the North-Eastern Atlantic, the Mediterranean and Connected Seas. For events in the north-western Atlantic ocean, advisory and watch messages are issued for earthquakes of magnitude 7.5<EQ>7.8 and M>7.9 respectively.

6.4 PTWS-TSP

Tsunami Service Providers of the Pacific Tsunami Warning and Mitigation System issue bulletins for all Pacific Ocean earthquakes which pose a tsunami threat to the coasts within their AoS. Bulletins are issued for earthquakes outside the Pacific Ocean which are assessed to have potential for generating a tsunami of ≥30 cm along the Pacific coasts.

7. ICG PRODUCTS

ICG-TSPs may generate two types of bulletins: Tsunami Public Bulletins and Tsunami Exchange Bulletins.

7.1 PUBLIC BULLETINS AND PRODUCTS

These bulletins will be widely distributed in various formats and through public and private communication systems (GTS, Email, Fax, Web, SMS, etc.) necessary to facilitate a broad reception, including the global media. There will be the first bulletin, and in the case of a potential threat, updates will be issued.

a. Bulletin 1. Will include earthquake parameters (latitude, longitude, depth, magnitude) and indicate if there is the potential for a destructive tsunami for a certain area. The potential for a destructive tsunami will be defined as potential, undetermined potential (for situations where the travel time is greater than 2 or 3 hours) or no potential. These bulletins will be issued within minutes of the earthquake.

b. Bulletin 2, 3, 4… These bulletins will provide an update on the earthquake parameters (latitude, longitude, depth, magnitude, and origin time), the threat level as assessed by the TSPs or as reported by the national authorities to the TSPs as the case may be in different ICGs.

7.2 NON-PUBLIC EXCHANGE BULLETINS AND PRODUCTS

These bulletins will be issued by the TSP to the NTWC/TWFP and may contain more detailed technical information required to make decisions at the national level. The distribution of the bulletins will be private and websites with the products will be password protected. There will be the first bulletin, and in the case of a potential threat, updates will be issued.

a. Bulletin 1. Will include earthquake parameters (latitude, longitude, depth, magnitude), level of tsunami threat, estimated times of arrival and estimated wave amplitude/inundation information. These bulletins will be issued within minutes of the earthquake.

b. Bulletin 2, 3, 4… These bulletins will provide an update on the earthquake parameters (latitude, longitude, depth, magnitude), the recorded/reported wave amplitudes, estimated and observed wave arrival times, run-up, maximum positive wave amplitude at shoreline (inundation). The supplementary bulletins will be issued when hourly updates are required, when higher-than-expected tsunami wave observations are received, or when the threat assessment has changed. However, the exchange bulletins issued for an event by each TSP shall be sequentially numbered regardless of the bulletin type.

c. Final Bulletin. This will be the last bulletin issued by the TSP for an event, indicating that the threat has passed, based on pre-defined criteria. This will form the basis for issue of Threat Cancellation or All Clear by the concerned authorities. A supplementary final bulletin may be issued if significant additional information becomes available.

NTWCs/TWFPs may categorize bulletins typically into the following four different threat levels based on potential impact:

Threat Level	Potential Impact
0	No impact expected, no flooding, no currents
1	There is a potential for tsunami impact, but given the travel time, no response of the public is necessary at the moment
2	Threat to coastal marine areas due to strong currents and oscillations in sea level
3	Threat of tsunami inundation

7.3 BULLETIN STRUCTURE

It is desirable that all ICG-TSPs use the similar layout and structure for their bulletins, which consist of some or all of these component sections, depending on the bulletin type:

Header – Indicates the issuing authority, bulletin number, which is sequential throughout an event, type of the bulletin and the date and time in UTC that the bulletin was issued.

Disclaimer Statement – It is important that the TSP bulletins contain appropriate disclaimers to clarify the information in the bulletins. An example of such statement to be issues by PTWS in the bulletins meant for the media and public could read as follows:

“MEDIA AND PUBLIC SHOULD NOTE THE FOLLOWING –

THIS STATEMENT IS ISSUED FOR INFORMATION ONLY IN SUPPORT OF THE UNESCO-IOC PACIFIC TSUNAMI WARNING AND MITIGATION SYSTEM AND IS MEANT FOR NATIONAL AUTHORITIES IN EACH COUNTRY OF THAT SYSTEM.

NATIONAL AUTHORITIES MAY DETERMINE AN INDEPENDENT... DIFFERENT... OR MORE REFINED LEVEL OF THREAT... AND THEY WILL ALSO DETERMINE THE APPROPRIATE LEVEL OF ALERT FOR THEIR COASTS AND MAY ISSUE ADDITIONAL OR MORE REFINED INFORMATION ON EXPECTED IMPACTS AND RECOMMENDED ACTIONS.”

Earthquake Parameters – comprising magnitude (Mw, as far as possible), depth (km), date and time of earthquake (UTC), latitude and longitude of earthquake epicenter, and location name of earthquake epicenter.

Tsunami Evaluation Statement – Based on preliminary earthquake parameters, the first bulletin may contain qualitative information on tsunamigenic potential of the earthquake (local / regional / ocean-wide). If model results indicate a THREAT, the evaluation message indicates that investigation is underway. If any sea-level gauge subsequently confirms the existence of a tsunami that is reported in this section, from the third bulletin onwards.

Tsunami Threat Information – If model results indicate a THREAT, this section is included from the second bulletin onwards and includes a list of regions/points where a THREAT is forecast to exist. For each threatened country the coastal zones under THREAT are listed with the expected wave arrival time in UTC for the first wave greater than an agreed threshold, and the expected maximum wave amplitude in metres for that zone.

Advice – Indicates that the bulletin is issued as an advice only and that the condition of the alert and determination of action based on threat status is up to national or local authorities.

Other Centres' Information – A statement regarding products that may be issued by other TSPs in the same ICG.

Next Bulletin – A statement indicating when the next bulletin will be issued, or in the case of Final Bulletins indicating that no further bulletins will be issued for the event.

Formats of TSP text and/or graphical products should be determined in the ICG considering the requirements of the TWFPs/NTWCs.

8. COMMON SPATIAL DATASET

The level of risk posed by tsunamis is well determined by understanding of complex spatial and temporal dependence among multiple datasets. It is unreasonable to expect individuals involved in disaster response management to analyze these complex interactions under emergency conditions without errors. When multiple centres are involved for the analysis, the possibility of misinterpretation increases due to multiple ways of data handling. To ensure interoperability between the multiple centres it is important to use a common spatial data for delivery of tsunami advisories.

TSPs can use this common spatial dataset for generation of public bulletins as well as detailed exchange bulletins. The NTWCs can use the information provided for each of its coastal regions to formulate its own national bulletins during an event. Use of common spatial data will not only facilitate inter-TSP performance comparisons but also enable NTWCs to realistically compare TSP products. Each element in the common spatial dataset represents a specific point/region along the coast that is well known to emergency managers and the populace. Each element is provided with model-derived information such as expected tsunami amplitude, expected time of arrival, threat level, etc. which enables the NTWCs to make a decision during the event. This common spatial dataset should be finalized in consultation with the NTWCs.

9. EVENT ASSESSMENTS & PROCEDURES

9.1 EVENT ASSESSMENTS

Post-event assessments and questionnaires are valuable. TOWS-WG, at its 8th meeting, recommended a standardized post-event assessment template for use by all ICGs. TSPs, in conjunction with the regional Tsunami Information Centre and/or ICG Secretariat shall conduct post-event assessments. The trigger for implementing an assessment should be a tsunami threat of >1 m amplitude forecast in 1 or more countries in a region. Over and above this trigger level, the final decision to implement a survey should be decided by the regional Tsunami Information Centre (TIC) in consultation with the ICG Steering Group and Secretariat taking into consideration whether the tsunami resulted in a national response in one or more countries.

9.2 PROCEDURE FOR INITIAL NAMING OF TSUNAMIGENIC EARTHQUAKES

Potentially tsunamigenic earthquakes (i.e. those requiring the issuing of Service Level 2 products) may be named by TSPs using a scheme based on the Flinn-Engdahl geographic designator plus the year of the event, plus a sequence number to allow for multiple events in the region within a calendar year. An example would be "Banda Sea-2013-1". A subsequent Banda Sea event in 2013 would be designated "Banda Sea-2013-2". If an event proves to be significant, the final name could be decided in consultation with the country in which it occurred.

9.3 PROCEDURE FOR HANDLING MULTIPLE EARTHQUAKES IN QUICK SUCCESSION

If multiple tsunamigenic earthquakes occur in quick succession and within the same earthquake source zone, it is desirable that TSPs include mention of the subsequent event in the bulletins they are already issuing for the first event, rather than commencing the issuing of a new series of bulletins, to avoid confusion at the NTWCs. It is important to take into consideration the time and spatial extent between the events. When successive tsunamigenic earthquakes are referred to in one bulletin, it should be made very clear in the initial part of the bulletin, so that the receiving centre understands that the bulletin is for a main shock, aftershock or a new event. Standard terminology in update bulletins should make clear reference to the subject of the update (earthquake parameters, aftershock, sea-level observations, threat levels and/or area of threat).

9.4 PROCEDURE FOR REPORTING OF ESTIMATED AND OBSERVED SEA LEVELS

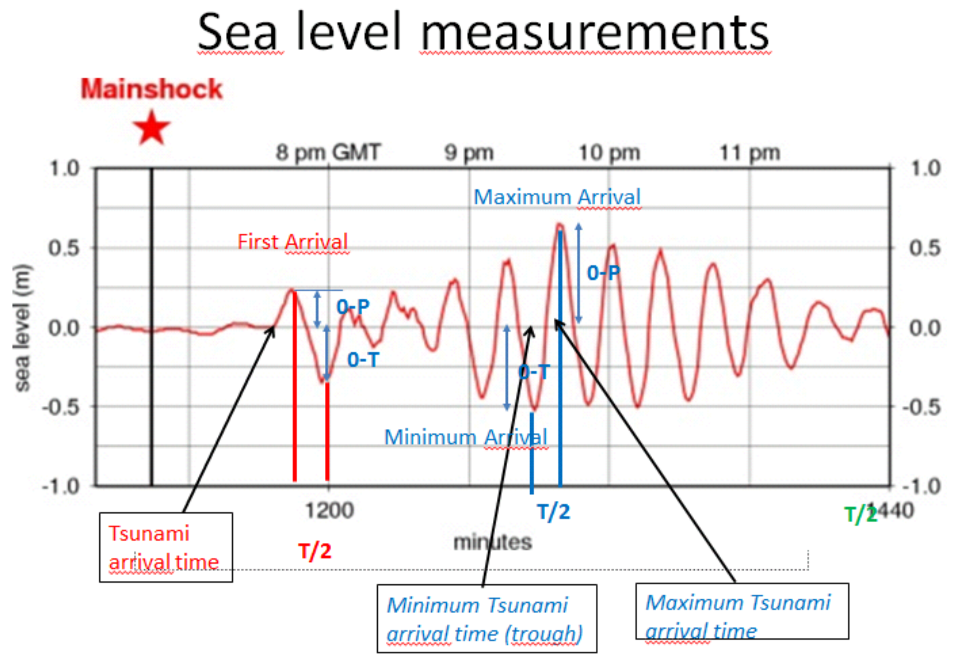
<u>Amplitude</u>: TSPs should use amplitude relative to sea level as the common measure of a tsunami and this should be clearly defined in the message. All TSPs should report forecast and observations as amplitude relative to sea level at the time of the forecast or observation. Amplitude is measured as 1) the absolute value of the difference between a particular peak or trough of the tsunami and sea level at that time, or 2) half the difference between an adjacent trough and peak and can be corrected for the change of tide between that trough and peak. Each TSP will specify the methodology and the parameters used for producing forecast amplitudes in its Service Definition Document.

<u>Arrival Times</u>: It is useful to report the following estimated and observed tsunami wave arrival times in the TSP bulletins:

- Estimated time of arrival of first tsunami wave (t1) with positive or negative amplitude as calculated by forecast model

- Observed time of arrival of first tsunami (o1) wave with positive or negative amplitude as measured by sea level stations
- Estimated time of arrival of first tsunami wave amplitude over basin-specific threat threshold (t2) with positive or negative amplitude as calculated by forecast model
- Observed time of arrival of tsunami wave with positive or negative amplitude over basin-specific threat threshold (o2) as measured by sea level stations
- Estimated time of arrival of maximum tsunami wave (t3) with positive amplitude as calculated by forecast model
- Observed time of arrival of maximum tsunami wave (o3) with positive amplitude as measured by sea level stations
- Estimated time of arrival of last tsunami wave (t4) with positive amplitude over basin-specific threat threshold as calculated by forecast model
- Observed time of arrival of last tsunami wave(o4) with positive amplitude over basin-specific threat threshold as measured by sea level stations
- Estimated time of arrival of minimum tsunami wave (t5) with negative amplitude as calculated by forecast model
- Observed time of arrival of minimum tsunami wave (o5) with negative amplitude as measured by sea level stations

As a minimum requirement, the Estimated Time of Arrival of the first tsunami wave (t1) and the Observed Time of maximum tsunami wave (o3) with maximum amplitude should be included by the TSPs in their bulletins



9.5 COMMUNICATIONS TESTS AND WAVE EXERCISES:

TSPs shall conduct regular Communication Tests in which TSPs send test notification messages to NTWCs/TWFPs. TSPs shall collaborate with the IOC/ICG Secretariat/Tsunami Information Centres in the preparation of the test and the IOC/ICG Secretariat shall announce the conduct of the test at least one month before the test. It is preferable that a Test Report is prepared within three months of the test. TSPs, NTWCs and TWFPs shall participate in ICG wave exercises in coordination with the IOC/ICG Secretariat and the Tsunami Information Centres.

10. DISSEMINATION METHODS

NTWCs/TWFPs and TSPs should use all possible means of communication available to them to reach the target groups. The most widely used means for dissemination of tsunami advisories/alerts in different ICGs are GTS, AFTN, FAX, email, Web, SMS, RSS, CAPS, AWIPS, NWW, NAWAS, HAWAS, IDN, CISN, etc. In addition to the above, the following methods may be most suitable for dissemination of public and exchange bulletins to specific target groups:

- TSPs to Public: Tsunami Public bulletins could be disseminated by GTS, Email, FAX, SMS, Websites. The IOC Public List Server may also be available for subscribers. In issuing TSPs bulletins to the public, it should be carefully taken into account that the bulletins should not cause confusion because of possible conflict with warnings issued by local authorities.
- TSPs to NTWCs/TWFPs: Detailed Non-public Tsunami Exchange bulletins could be privately disseminated by password protected websites. A brief notification alerting the NTWCs/TWFPs to the issue of a detailed bulletin could be sent by GTS, Email, FAX, SMS, etc.
- NTWCs/TWFPs to TSPs: SITREPS or Warning Status reports from NTWCs/TWFPs to TSPs could be sent by Email, Telephone, FAX, Websites, etc.
- NTWCs/TWFPs to Public: Public alerting could be done through Email, SMS, Websites, TV/Radio, Loudspeakers, Sirens and other traditional methods.

Procedures for disseminating bulletins for events outside the TSP Areas of Service

For events outside the Earthquake Source Zones of the ICGs, the ICG-TSPs will send Public Bulletins and/or Notification Messages to the IOC Public List Server and the GTS only for events above an earthquake magnitude or forecast wave amplitude that could potentially impact coasts at a hazard level within their AoS. General guidelines regarding the structure and content of the Public Bulletins and Notification Messages to be adopted by all the ICGs needs to be finalized. Bulletins relayed to the IOC Public List Server by the ICG-TSPs should be the public bulletins generated by the ICG-TSPs as approved by the respective ICGs

11. KEY PERFORMANCE INDICATORS

The following key performance indicators are proposed, to measure performance of the TSPs. The target values mentioned against each of the parameter are only indicative and detailed investigation in both scientific and sociological means should be further conducted to arrive at the exact values. These parameters could vary between different ICGs, based on the local seismo-tectonic settings, available warning times, etc. It should be noted that there are no absolute measures for criteria such as earthquake magnitude, and that accuracy can only be best gauged in some cases by comparing analyzed values amongst agencies (i.e. absolute accuracy may not be known).

11.1 TSP PERFORMANCE

No.	Key Performance Indicator	Target Value
	Earthquake Detection	
1.	Elapsed time of 1st (EQ) Bulletin for TSP Area of Service	10 minutes (when no coordination required between TSPs)
2.	Probability of Detection of EQ with basin-defined minimum magnitude threshold, in comparison with final estimate from USGS after one month	100%
3.	Accuracy of EQ parameters in comparison with final estimate from USGS after one month:	Magnitude: 0.3 Depth: 30 km Location: 30 km
	Threat Assessment	
4.	Elapsed time of issuing first threat assessment bulletin after EQ	20 minutes (when no coordination required between TSPs)
5.	Probability of detection of tsunamis above basin specific threat threshold	100%
6.	Accuracy of tsunami amplitude forecasts	factor of 2

**Figures to be verified and adjusted according to basin and nature of threat by each ICG*

11.2 TSUNAMI SERVICE PROVIDER (TSP) FUNCTIONAL STATUS

No.	Key Performance Indicator	Target Value
1.	Operational 24 hours/day, seven days /week (24/7)	99%
2.	Notify TWFPs and NTWCs of planned major service changes	> 3 months
3.	Notify TWFPs and NTWCs of planned major interruptions	> 3 months
4.	Return to service after planned interruptions	< 1 day
5.	Return to service after unplanned interruptions in an event	<30 mins

11.3 NATIONAL TSUNAMI WARNING CENTRE (NTWC) FUNCTIONAL STATUS

No.	Key Performance Indicator	Target Value
1.	Notify authorities of planned service changes	> 3 months
2.	Notify authorities of planned interruptions	> 3 months
3.	Return to service after planned interruptions	< 1 day
4.	Return to service after unplanned interruptions	<30 mins
5.	Elapsed time of issuing tsunami warnings and other related statements according to SOPs	< 10 mins after earthquake for local and 30 mins for regional tsunami threat to their country
6.	Notify IOC of changes to Tsunami Warning Focal Point information	< 1 week
7.	Maintain an overlap period between the old TWFP contact information and the new TWFP contact information to allow time for the IOC and TSPs to implement the change	> 3 months

11.4 TSUNAMI WARNING FOCAL POINT (TWFP) FUNCTIONAL STATUS

No.	Key Performance Indicator	Target Value
1.	Operational 24 hours/day, seven days /week (24/7)	99%
2.	Notify authorities of planned service changes	> 3 months
3.	Notify authorities of planned interruptions	> 3 months
4.	Return to service after planned interruptions	< 1 day
5.	Return to service after unplanned interruptions	<30 mins
6.	Notify IOC of changes to Tsunami Warning Focal Point information	< 1 week
7.	Maintain an overlap period between the old TWFP contact information and the new TWFP contact information to allow time for the IOC and TSPs to implement the change	> 3 months
8.	Elapsed time of disseminating TSP bulletins according to Standard Operating Procedures	< 10 mins after TSP bulletin issuance for local and regional tsunami threat to their country

12. LIMITATIONS OF THE SYSTEMS/PROCEDURES

The science of rapidly and accurately forecasting tsunamis has made important strides in recent years but challenges remain. Limitations of warning systems should be known and understood in order to best plan for and execute an appropriate response. For example, the current tsunami warning systems are designed to provide tsunami forecast information for tsunamis caused by submarine and coastal earthquakes; not those caused by other sources such as submarine and coastal landslides, volcanoes, etc.

The greatest unknown about the tsunami in real-time (and even later) is the nature of earthquake. How did the seafloor deform? How much was it displaced up or down and over what areas? Models all make assumptions about the source based upon the seismic analysis or later upon nearby sea level gauge readings, but they only approximate the actual rupture geometry. The second greatest unknown is how the tsunami will interact with the coast. In most cases a general approximation must be used. Even when detailed coastal inundation models are available, properly capturing coastal resonances, trapped wave energy, and multiple wave interactions after even a few wave cycles is not possible. For these reasons, the forecast model information provided in the TSP products should be viewed with care, taking into consideration the limitations that are explained later in this document.

12.1 EARTHQUAKE PARAMETERS

Earthquake parameters provide the earliest indication of a potential tsunami because seismic waves travel much faster around the earth than tsunami waves. Consequently, the fastest initial tsunami warnings are based entirely on the preliminary earthquake parameters. However, sometimes warnings based on large earthquakes with the potential to generate a widespread destructive tsunami are cancelled when significant tsunami waves are not observed. A number of factors contribute to this limitation, most importantly when the tsunami is generated by predominately strike-slip fault. In this case vertical seafloor displacement is usually very small, and generated tsunami can be small comparing to the magnitude. On the other hand, tsunami earthquakes with slow but large rupture may generate larger tsunami than expected from magnitude.

12.2 INITIAL ESTIMATED ARRIVAL TIMES AND WAVE AMPLITUDES

Initial estimated arrival times are typically computed from the epicenter of the earthquake to each forecast point using the physics principle that a wave will travel from point A to point B through the fastest path. There are two limitations to this method. The first is the inaccuracy of representing the tsunami source by a point located at the epicenter. For great earthquakes, the ones most likely to produce a tsunami, the earthquake rupture will start at the epicenter but it can extend for tens or even hundreds of kilometers away from the epicenter. As a consequence, the tsunami source may not be like a point and it may not be located at the epicenter.

The second limitation is that the fastest path from the epicenter to the forecast point may not be a path over which much energy has traveled. Consequently, the first arriving tsunami waves may be small compared to later arriving waves. The net result of both limitations is that significant tsunami waves may arrive tens of minutes sooner or later than the predicted arrival time and that such errors may be largest in the biggest events.

At present it is not possible to quickly know the precise dimensions or location of the tsunami source. These parameters may only become available once the tsunami forecast model is sufficiently constrained with sea level readings, and this methodology is still untested for major events and is in its implementation stage. Consequently, for now, estimated tsunami arrival times must be used cautiously and conservatively, expecting that tsunami impact could be sooner or later than predicted.

Tsunami amplitude directly depends on coastal bathymetry. While steep slopes reflect waves, gentle slopes increase their amplitude. Likewise, an island can be protected by its coral reef "breaking" the waves. Tsunami waves can be amplified by many factors such as in case of rivers which penetrate deep inland, forming a narrow gully through which the rushing water creates a tidal bore. Likewise, in closed spaces such as harbours and bays, the waves may succeed one another at 10- to 20-minute intervals, creating a resonance effect, with strong currents and eddies. In the absence of accurate bathymetry data of all coastal regions, the wave amplitudes at the coast are approximated conservatively using Green’s Law estimating that the tsunami amplitude could be higher or lower than the actual.

12.3 AREA OF THREAT AND NO THREATS

Any particular coastal area is assigned to threat only based on whether the estimated wave amplitude is exceeding a pre-decided threshold and the area is under respective ICG's area of responsibility. Historical data and numerical model outputs show that tsunamis do not affect all areas equally. Significant differences can be due to directionality associated with the source, focusing and defocusing by bathymetry, attenuation by spreading and friction, and blockage by land masses. Consequently, some areas currently put into threat status may not actually be threatened.

13. TRAINING AND CAPACITY BUILDING

Timely and accurate dissemination of warnings is an essential part of an end-to-end warning system and requires the development of inter-institutional agreements among stakeholder organizations as well as SOPs for activation of the warning process. Organizational tsunami SOPs can be utilized to ensure that warnings will be transmitted from the TWFP out to critical response agencies and down to vulnerable, at-risk communities. Regular SOP trainings need to be organized to develop protocols which define: (i) the roles and responsibilities of each organization; (ii) paths of communication between organizations, including which organizations communicate with others and how; and (iii) the hierarchy of decision makers for whether, where and when to call for evacuations.

It is essential that the communities that are vulnerable to the effects of tsunami are made aware of the effects and how to respond when tsunami happens through simple cost-effective and cultural sensitive awareness programmes. Such programmes would include developing and disseminating information through the media, workshops/seminars, awareness materials, Internet, signage and billboards. If not already in existence, tsunami-related curriculum programmes should be developed to build that inherent capability in young adults and children.

Due to the nature of tsunami, Member States must be able to respond and this will require putting in place plans and processes to enable effective response coordination. These plans and processes would include response management structures, responsibilities, evacuation arrangements and communication systems. Member States should also plan and conduct exercises on a regular basis to test early warning systems and emergency evacuation.

To ensure that governments, NGOs, private sector and community representatives are able to provide the required response, sustainable capacity building programmes should be developed and delivered.

14. CONCLUSION

This Global Service Definition Document (GSDD) describes global tsunami warning services that are provided by regional tsunami warning systems operating in different ocean basins as a global system of systems and coordinated by the Intergovernmental Oceanographic Commission. The content is based on decisions made in the earlier meetings of the Task Team on Tsunami Watch Operations (TTTWO) and approved by the TOWS-WG. This is intended to be a living document that will undergo additions and modifications to the global services as finalized by the TTTWO from time to time as it works towards accomplishing its ToR towards global harmonization of tsunami watch operations.

It may be noted that the suggestions and recommendations put forth in this document are based on best-practice and intend to serve only as a broad guidance to the ICGs in planning and development of their systems. While the specific requirements of each region will continue to drive the evolution of each ICG, following a common framework, as put forth in this document, will ensure that operations within and among different regional systems become seamless and interoperable. The task of harmonization of tsunami watch operations is a continuing one and as proposed in this document, is to be driven by representatives of the major stakeholders, i.e. all the ICGs.

ANNEX I

Earthquake Source Maps of Tsunami Warning Systems

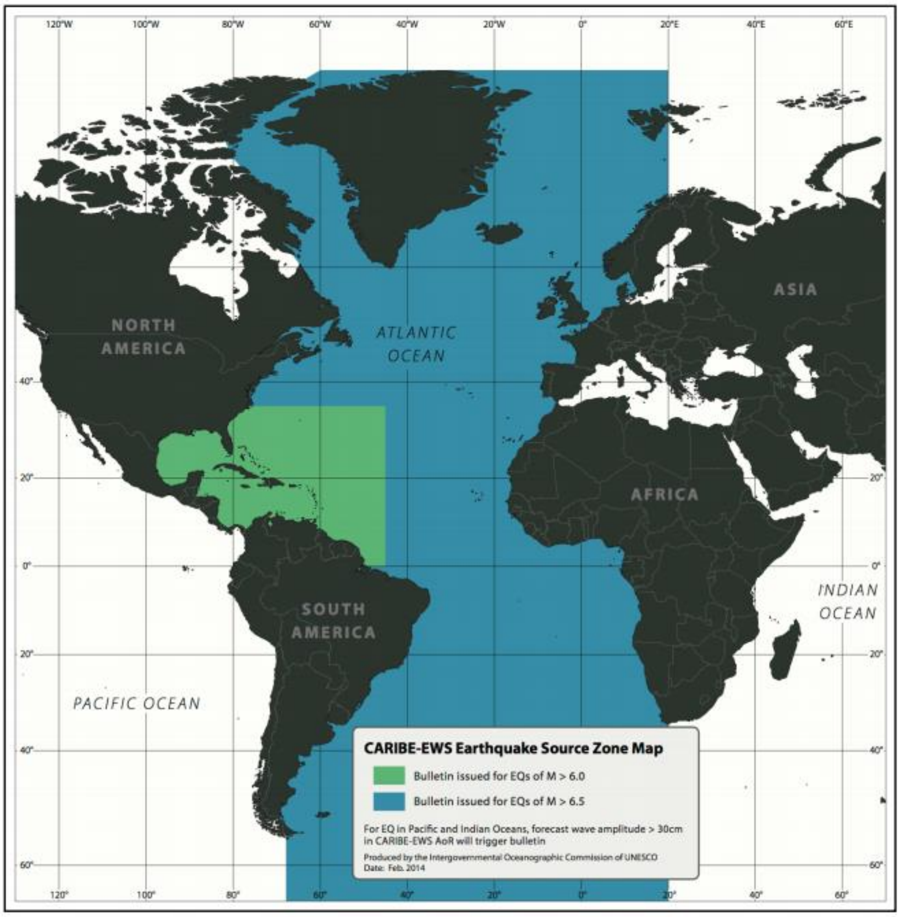


Figure: CARIBE-EWS Earthquake Source Zone Map
(Reference: IOC/TOWS-WG-VII/3 Annex V, page 19)

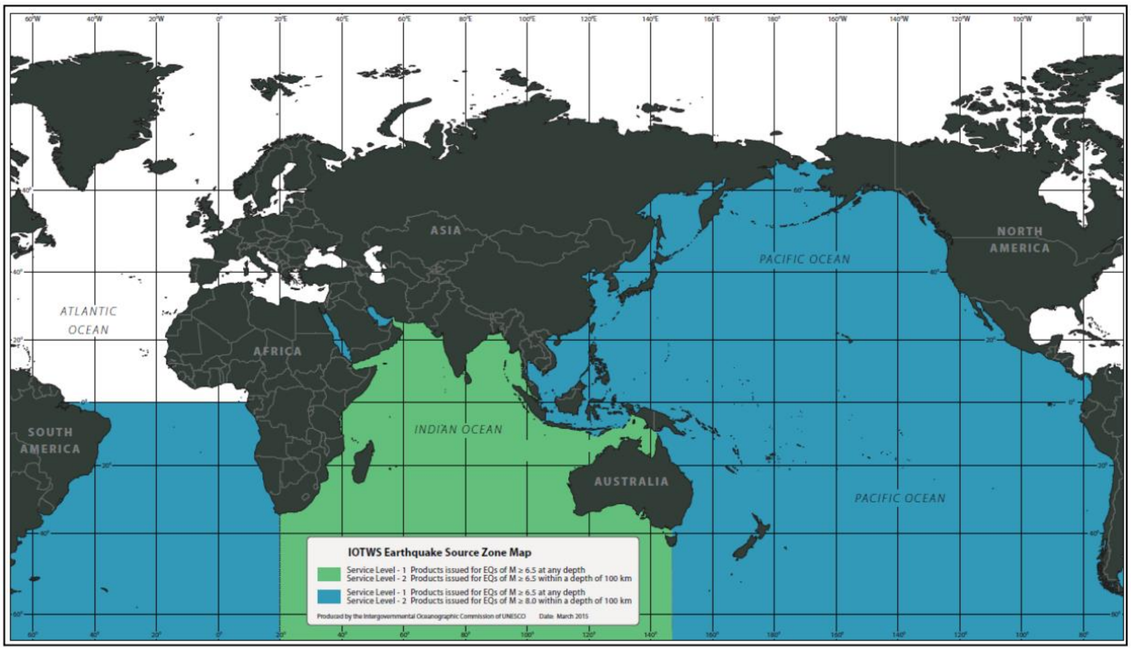


Figure: IOTWS-TWS Earthquake Source Zone Map
(Reference: IOC/TOWS-WG-VIII/3 Annex VI, page 14)

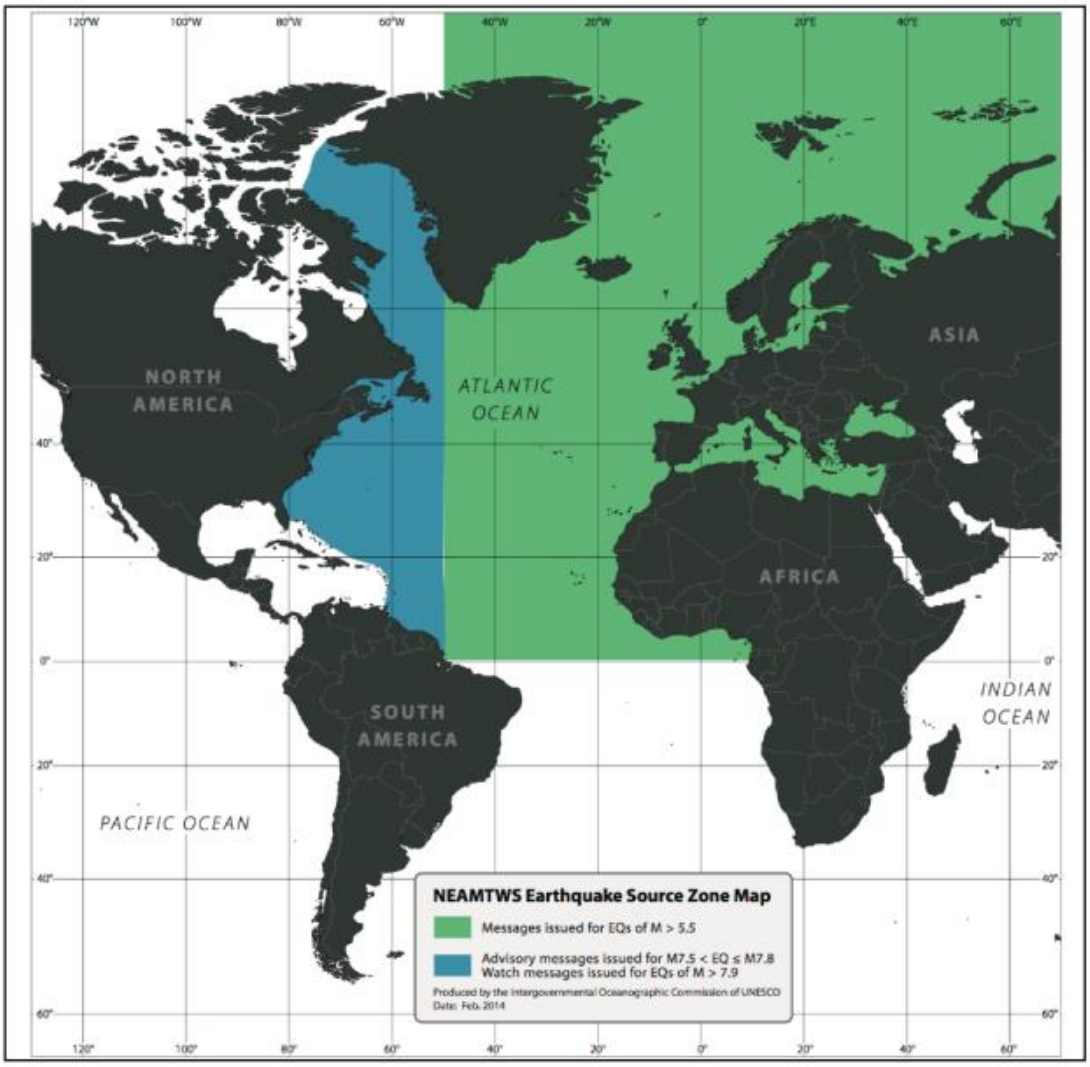


Figure: NEAMTWS Earthquake Source Zone Map
(Reference: IOC/TOWS-WG-VII/3 Annex V, page 21)

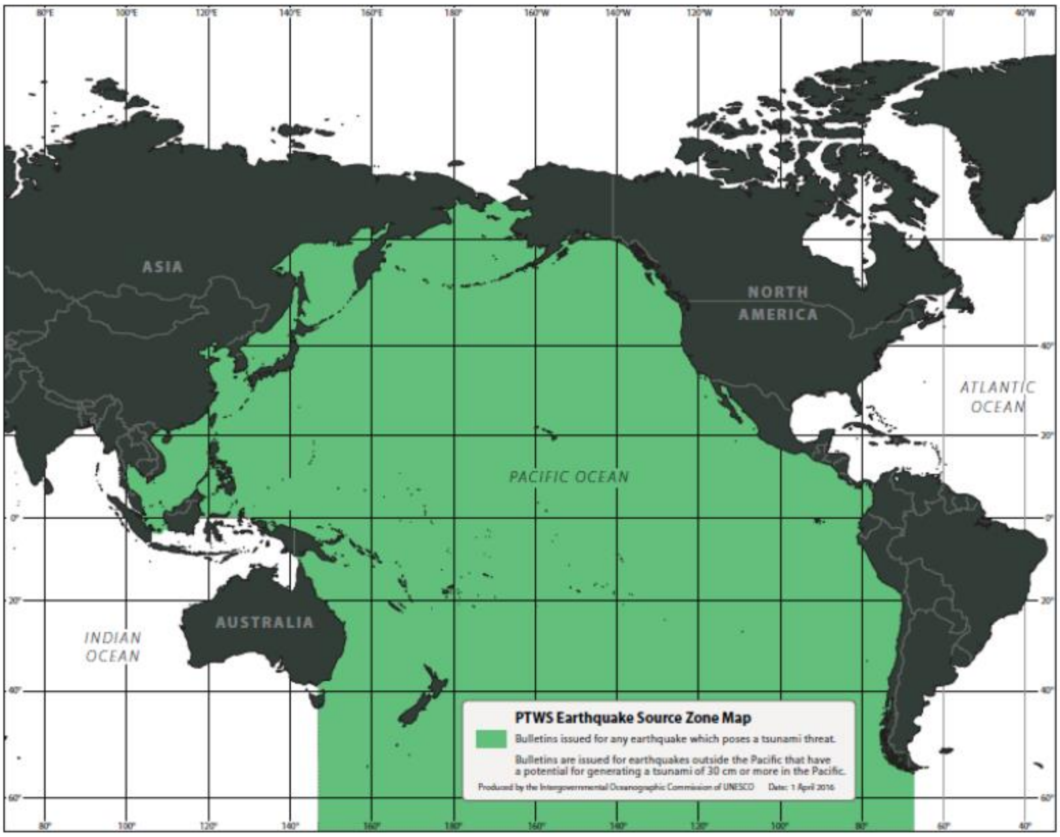


Figure: PTWS Earthquake Source Zone Map
(Reference: IOC/TOWS-WG-IX/3 Annex IV, page 52)

ANNEX II

List of Acronyms

AoR	Areas of Responsibility
AoS	Areas of Service
CARIBE-EWS	Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions
CARIBE-EWS-TSP	CARIBE-EWS Tsunami Service Provider
CFP	Coastal Forecast Point
CTBTO	Comprehensive Nuclear Test Ban Treaty Organization
EQ	Earthquake
GFZ	German Research Centre for Geosciences
GSN	Global Seismographic Network
GTS	Global Telecommunication System
ICG	Intergovernmental Coordination Group
ICG/CARIBE-EWS	Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions
ICG/IOTWMS	Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
ICG/NEAMTWS	Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas
ICG/PTWS	Report from the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System
IOC	Intergovernmental Oceanographic Commission [UNESCO]
IOTWMS	Indian Ocean Tsunami Warning and Mitigation System
IOTWMS-TSP	IOTWMS Tsunami Service Provider
IRIS	Incorporated Research Institutions for Seismology
KPI	Key Performance Indicators
NEAM	North-Eastern Atlantic, the Mediterranean and Connected Seas region
NEAMTWS	Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas
NEAMTWS-TSP	NEAMTWS Tsunami Service Provider
NTWC	National Tsunami Warning Centre
PTWC	Pacific Tsunami Warning Centre
PTWS	Pacific Tsunami Warning and Mitigation System (formerly ITSU)
PTWS-TSP	PTWS Tsunami Service Provider
SOP	Standard Operating Procedure

TOWS-WG	Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems
TSP	Tsunami Service Provider
TTTWO	Task Team on Tsunami Watch Operations
TWFP	Tsunami Warning Focal Point
TNC	Tsunami National Contact
TWS	Tsunami Warning System
UNESCO	United Nations Educational, Scientific and Cultural Organization
USGS	United States Geological Survey
WG	Working Group

IOC Technical Series

No.	Title	Languages
1	Manual on International Oceanographic Data Exchange. 1965	(out of stock)
2	Intergovernmental Oceanographic Commission (Five years of work). 1966	(out of stock)
3	Radio Communication Requirements of Oceanography. 1967	(out of stock)
4	Manual on International Oceanographic Data Exchange - Second revised edition. 1967	(out of stock)
5	Legal Problems Associated with Ocean Data Acquisition Systems (ODAS). 1969	(out of stock)
6	Perspectives in Oceanography, 1968	(out of stock)
7	Comprehensive Outline of the Scope of the Long-term and Expanded Programme of Oceanic Exploration and Research. 1970	(out of stock)
8	IGOSS (Integrated Global Ocean Station System) - General Plan Implementation Programme for Phase I. 1971	(out of stock)
9	Manual on International Oceanographic Data Exchange - Third Revised Edition. 1973	(out of stock)
10	Bruun Memorial Lectures, 1971	E, F, S, R
11	Bruun Memorial Lectures, 1973	(out of stock)
12	Oceanographic Products and Methods of Analysis and Prediction. 1977	E only
13	International Decade of Ocean Exploration (IDOE), 1971-1980. 1974	(out of stock)
14	A Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment and Baseline Study Guidelines. 1976	E, F, S, R
15	Bruun Memorial Lectures, 1975 - Co-operative Study of the Kuroshio and Adjacent Regions. 1976	(out of stock)
16	Integrated Ocean Global Station System (IGOSS) General Plan and Implementation Programme 1977-1982. 1977	E, F, S, R
17	Oceanographic Components of the Global Atmospheric Research Programme (GARP) . 1977	(out of stock)
18	Global Ocean Pollution: An Overview. 1977	(out of stock)
19	Bruun Memorial Lectures - The Importance and Application of Satellite and Remotely Sensed Data to Oceanography. 1977	(out of stock)
20	A Focus for Ocean Research: The Intergovernmental Oceanographic Commission - History, Functions, Achievements. 1979	(out of stock)
21	Bruun Memorial Lectures, 1979: Marine Environment and Ocean Resources. 1986	E, F, S, R
22	Scientific Report of the Interealibration Exercise of the IOC-WMO-UNEP Pilot Project on Monitoring Background Levels of Selected Pollutants in Open Ocean Waters. 1982	(out of stock)
23	Operational Sea-Level Stations. 1983	E, F, S, R
24	Time-Series of Ocean Measurements. Vol.1. 1983	E, F, S, R
25	A Framework for the Implementation of the Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment. 1984	(out of stock)
26	The Determination of Polychlorinated Biphenyls in Open-ocean Waters. 1984	E only
27	Ocean Observing System Development Programme. 1984	E, F, S, R
28	Bruun Memorial Lectures, 1982: Ocean Science for the Year 2000. 1984	E, F, S, R
29	Catalogue of Tide Gauges in the Pacific. 1985	E only
30	Time-Series of Ocean Measurements. Vol. 2. 1984	E only
31	Time-Series of Ocean Measurements. Vol. 3. 1986	E only
32	Summary of Radiometric Ages from the Pacific. 1987	E only
33	Time-Series of Ocean Measurements. Vol. 4. 1988	E only
34	Bruun Memorial Lectures, 1987: Recent Advances in Selected Areas of Ocean Sciences in the Regions of the Caribbean, Indian Ocean and the Western Pacific. 1988	Composite E, F, S
35	Global Sea-Level Observing System (GLOSS) Implementation Plan. 1990	E only

(continued)

36	Bruun Memorial Lectures 1989: Impact of New Technology on Marine Scientific Research. 1991	Composite E, F, S
37	Tsunami Glossary - A Glossary of Terms and Acronyms Used in the Tsunami Literature. 1991	E only
38	The Oceans and Climate: A Guide to Present Needs. 1991	E only
39	Bruun Memorial Lectures, 1991: Modelling and Prediction in Marine Science. 1992	E only
40	Oceanic Interdecadal Climate Variability. 1992	E only
41	Marine Debris: Solid Waste Management Action for the Wider Caribbean. 1994	E only
42	Calculation of New Depth Equations for Expendable Bathymerographs Using a Temperature-Error-Free Method (Application to Sippican/TSK T-7, T-6 and T-4 XBTS. 1994	E only
43	IGOSS Plan and Implementation Programme 1996-2003. 1996	E, F, S, R
44	Design and Implementation of some Harmful Algal Monitoring Systems. 1996	E only
45	Use of Standards and Reference Materials in the Measurement of Chlorinated Hydrocarbon Residues. 1996	E only
46	Equatorial Segment of the Mid-Atlantic Ridge. 1996	E only
47	Peace in the Oceans: Ocean Governance and the Agenda for Peace; the Proceedings of *Pacem in Maribus* XXIII, Costa Rica, 1995. 1997	E only
48	Neotectonics and fluid flow through seafloor sediments in the Eastern Mediterranean and Black Seas - Parts I and II. 1997	E only
49	Global Temperature Salinity Profile Programme: Overview and Future. 1998	E only
50	Global Sea-Level Observing System (GLOSS) Implementation Plan-1997. 1997	E only
51	L'état actuel de 1'exploitation des pêcheries maritimes au Cameroun et leur gestion intégrée dans la sous-région du Golfe de Guinée *(cancelled)*	F only
52	Cold water carbonate mounds and sediment transport on the Northeast Atlantic Margin. 1998	E only
53	The Baltic Floating University: Training Through Research in the Baltic, Barents and White Seas - 1997. 1998	E only
54	Geological Processes on the Northeast Atlantic Margin (8th training-through-research cruise, June-August 1998). 1999	E only
55	Bruun Memorial Lectures, 1999: Ocean Predictability. 2000	E only
56	Multidisciplinary Study of Geological Processes on the North East Atlantic and Western Mediterranean Margins (9th training-through-research cruise, June-July 1999). 2000	E only
57	Ad hoc Benthic Indicator Group - Results of Initial Planning Meeting, Paris, France, 6-9 December 1999. 2000	E only
58	Bruun Memorial Lectures, 2001: Operational Oceanography – a perspective from the private sector. 2001	E only
59	Monitoring and Management Strategies for Harmful Algal Blooms in Coastal Waters. 2001	E only
60	Interdisciplinary Approaches to Geoscience on the North East Atlantic Margin and Mid-Atlantic Ridge (10th training-through-research cruise, July-August 2000). 2001	E only
61	Forecasting Ocean Science? Pros and Cons, Potsdam Lecture, 1999. 2002	E only
62	Geological Processes in the Mediterranean and Black Seas and North East Atlantic (11th training-through-research cruise, July- September 2001). 2002	E only
63	Improved Global Bathymetry – Final Report of SCOR Working Group 107. 2002	E only
64	R. Revelle Memorial Lecture, 2006: Global Sea Levels, Past, Present and Future. 2007	E only
65	Bruun Memorial Lectures, 2003: Gas Hydrates – a potential source of energy from the oceans. 2003	E only
66	Bruun Memorial Lectures, 2003: Energy from the Sea: the potential and realities of Ocean Thermal Energy Conversion (OTEC). 2003	E only

67	Interdisciplinary Geoscience Research on the North East Atlantic Margin, Mediterranean Sea and Mid-Atlantic Ridge (12th training-through-research cruise, June-August 2002). 2003	E only
68	Interdisciplinary Studies of North Atlantic and Labrador Sea Margin Architecture and Sedimentary Processes (13th training-through-research cruise, July-September 2003). 2004	E only
69	Biodiversity and Distribution of the Megafauna / Biodiversité et distribution de la mégafaune. 2006 Vol.1 The polymetallic nodule ecosystem of the Eastern Equatorial Pacific Ocean / Ecosystème de nodules polymétalliques de l'océan Pacifique Est équatorial Vol.2 Annotated photographic Atlas of the echinoderms of the Clarion-Clipperton fracture zone / Atlas photographique annoté des échinodermes de la zone de fractures de Clarion et de Clipperton Vol.3 Options for the management and conservation of the biodiversity — The nodule ecosystem in the Clarion Clipperton fracture zone: scientific, legal and institutional aspects	E F
70	Interdisciplinary geoscience studies of the Gulf of Cadiz and Western Mediterranean Basin (14th training-through-research cruise, July-September 2004). 2006	E only
71	Indian Ocean Tsunami Warning and Mitigation System, IOTWS. Implementation Plan, 7–9 April 2009 (2nd Revision). 2009	E only
72	Deep-water Cold Seeps, Sedimentary Environments and Ecosystems of the Black and Tyrrhenian Seas and the Gulf of Cadiz (15th training-through-research cruise, June–August 2005). 2007	E only
73	Implementation Plan for the Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas (NEAMTWS), 2007–2011. 2007 *(electronic only)*	E only
74	Bruun Memorial Lectures, 2005: The Ecology and Oceanography of Harmful Algal Blooms – Multidisciplinary approaches to research and management. 2007	E only
75	National Ocean Policy. The Basic Texts from: Australia, Brazil, Canada, China, Colombia, Japan, Norway, Portugal, Russian Federation, United States of America. (Also Law of Sea Dossier 1). 2008	E only
76	Deep-water Depositional Systems and Cold Seeps of the Western Mediterranean, Gulf of Cadiz and Norwegian Continental margins (16th training-through-research cruise, May–July 2006). 2008	E only
77	Indian Ocean Tsunami Warning and Mitigation System (IOTWS) – 12 September 2007 Indian Ocean Tsunami Event. Post-Event Assessment of IOTWS Performance. 2008	E only
78	Tsunami and Other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE EWS) – Implementation Plan 2013–2017 (Version 2.0). 2013	E only
79	Filling Gaps in Large Marine Ecosystem Nitrogen Loadings Forecast for 64 LMEs – GEF/LME global project Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems. 2008	E only
80	Models of the World's Large Marine Ecosystems. GEF/LME Global Project Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems. 2008	E only
81	Indian Ocean Tsunami Warning and Mitigation System (IOTWS) – Implementation Plan for Regional Tsunami Watch Providers (RTWP). 2008	E only
82	Exercise Pacific Wave 08 – A Pacific-wide Tsunami Warning and Communication Exercise, 28–30 October 2008. 2008	E only
83.	*Cancelled*	
84.	Global Open Oceans and Deep Seabed (GOODS) Bio-geographic Classification. 2009	E only
85.	Tsunami Glossary	E, F, S
86	Pacific Tsunami Warning System (PTWS) Implementation Plan	*Electronic publication*

(continued)

87.	Operational Users Guide for the Pacific Tsunami Warning and Mitigation System (PTWS) – Second Edition. 2011	E only
88.	Exercise Indian Ocean Wave 2009 (IOWave09) – An Indian Ocean-wide Tsunami Warning and Communication Exercise – 14 October 2009. 2009	E only
89.	Ship-based Repeat Hydrography: A Strategy for a Sustained Global Programme. 2009	E only
90.	12 January 2010 Haiti Earthquake and Tsunami Event Post-Event Assessment of CARIBE EWS Performance. 2010	E only
91.	Compendium of Definitions and Terminology on Hazards, Disasters, Vulnerability and Risks in a coastal context	*Under preparation*
92.	27 February 2010 Chile Earthquake and Tsunami Event – Post-Event Assessment of PTWS Performance (Pacific Tsunami Warning System). 2010	E only
93.	Exercise CARIBE WAVE 11 / LANTEX 11—A Caribbean Tsunami Warning Exercise, 23 March 2011	
	Vol. 1 Participant Handbook / Exercise CARIBE WAVE 11 —Exercice d’alerte au tsunami dans les Caraïbes, 23 mars 2011. Manuel du participant / Ejercicio Caribe Wave 11. Un ejercicio de alerta de tsunami en el Caribe, 23 de marzo de 2011. Manual del participante. 2010	E/F/S
	Vol. 2 Report. 2011	E only
	Vol. 3 Supplement: Media Reports. 2011	E/F/S
94.	Cold seeps, coral mounds and deep-water depositional systems of the Alboran Sea, Gulf of Cadiz and Norwegian continental margin (17th training-through-research cruise, June–July 2008)	E only
95.	International Post-Tsunami Survey for the 25 October 2010 Mentawai, Indonesia Tsunami	E only
96.	Pacific Tsunami Warning System (PTWS) 11 March 2011 Off Pacific coast of Tohoku, Japan, Earthquake and Tsunami Event. Post-Event Assessment of PTWS Performance	E only
97.	Exercise PACIFIC WAVE 11: A Pacific-wide Tsunami Warning and Communication Exercise, 9–10 November 2011	
	Vol. 1 Exercise Manual. 2011	E only
	Vol. 2 Report. 2013	E only
98.	Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and connected seas. First Enlarged Communication Test Exercise (ECTE1). Exercise Manual and Evaluation Report. 2011	E only
99.	Exercise INDIAN OCEAN WAVE 2011 – An Indian Ocean-wide Tsunami Warning and Communication Exercise, 12 October 2011	E only
	Vol. 1 Exercise Manual. 2011 Supplement: Bulletins from the Regional Tsunami Service Providers	
	Vol. 2 Exercise Report. 2013	
100.	Global Sea Level Observing System (GLOSS) Implementation Plan – 2012. 2012	E only
101.	Exercise Caribe Wave/Lantex 13. A Caribbean Tsunami Warning Exercise, 20 March 2013. Volume 1: Participant Handbook. 2012	E only
102.	Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas — Second Enlarged Communication Test Exercise (CTE2), 22 May 2012. Vol. 1 Exercise Manual. 2012 Vol. 2 Evaluation Report. 2014	E only
103.	Exercise NEAMWAVE 12. A Tsunami Warning and Communication Exercise for the North-eastern Atlantic, the Mediterranean, and Connected Seas Region, 27–28 November 2012. Vol. 1: Exercise Manual. 2012 Vol. 2: Evaluation Report. 2013	E only
104.	Seísmo y tsunami del 27 de agosto de 2012 en la costa del Pacífico frente a El Salvador, y seísmo del 5 de septiembre de 2012 en la costa del Pacífico frente a Costa Rica. Evaluación subsiguiente sobre el funcionamiento del Sistema de Alerta contra los Tsunamis y Atenuación de sus Efectos en el Pacífico. 2012	Español solamente (resumen en inglés y francés)
105.	Users Guide for the Pacific Tsunami Warning Center Enhanced Products for the Pacific Tsunami Warning System, August 2014. Revised Edition. 2014	E, S

106.	Exercise Pacific Wave 13. A Pacific-wide Tsunami Warning and Enhanced Products Exercise, 1–14 May 2013. Vol. 1 Exercise Manual. 2013 Vol. 2 Summary Report. 2013	E only
107.	Tsunami Public Awareness and Educations Strategy for the Caribbean and Adjacent Regions. 2013	E only
108.	Pacific Tsunami Warning and Mitigation System (PTWS) Medium-Term Strategy, 2014−2021. 2013	E only
109.	Exercise Caribe Wave/Lantex 14. A Caribbean and Northwestern Atlantic Tsunami Warning Exercise, 26 March 2014. Vol. 1 Participant Handbook. 2014	E/S
110.	Directory of atmospheric, hydrographic and biological datasets for the Canary Current Large Marine Ecosystem, 2nd edition: revised and expanded. 2016	E only
111.	Integrated Regional Assessments in support of ICZM in the Mediterranean and Black Sea Basins. 2014	E only
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113.	Exercise Indian Ocean Wave 2014: An Indian Ocean-wide Tsunami Warning and Communication Exercise.	E only
114.	Exercise NEAMWAVE 14. A Tsunami Warning and Communication Exercise for the North-Eastern Atlantic, the Mediterranean, and Connected Seas Region, 28–30 October 2014 Vol. 1 Manual Vol. 2 Evaluation Report – Supplement: Evaluation by Message Providers and Civil Protection Authorities	E only
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121.	Exercise Indian Ocean Wave 14, an Indian Ocean wide Tsunami Warning and Communications Exercise, 9–10 September 2014	*In preparation*
122.	Tsunami Early Warning and Mitigation System in the North-Eastern Atlantic, the Mediterranean and Connected Seas. Sixth Communication Test Exercise (CTE6), 29 July 2015. Vol. 1: Exercise Manual Vol. 2: Evaluation Report	E only
123	Preparing for the next tsunami in the North-Eastern Atlantic, the Mediterranean and Connected Seas – Ten years of the Tsunami Warning System (NEAMTWS)	*In preparation*
124	Indicadores Marino Costeros del Pacífico Sudeste / Coastal and Marine Indicators of the Southeast Pacific (SPINCAM)	E/S
125	Exercise CARIBE WAVE 2016: A Caribbean and Adjacent Regions Tsunami Warning Exercise, 17 March 2016 (Venezuela and Northern Hispaniola Scenarios) Volume 1: Participant Handbook	E only

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127	How to reduce coastal hazard risk in your community – A step by step approach	E only
128.	Exercise Indian Ocean Wave 2016: An Indian Ocean-wide Tsunami Warning and Communications Exercise, 7–8 September 2016 Vol 1: Participant Manual Vol. 2: Evaluation report (with supplements)	E only
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