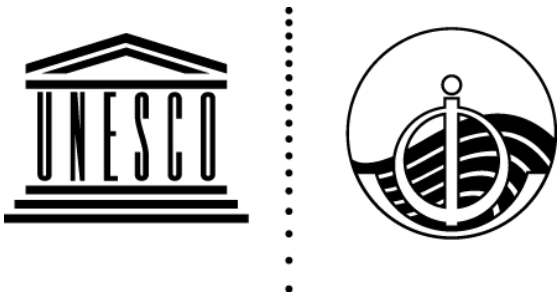
Intergovernmental Oceanographic Commission
Technical Series
142



Users' Guide for the Northwest Pacific Tsunami Advisory Center (NWPTAC)

Enhanced Products for the Pacific Tsunami Warning System

UNESCO

Intergovernmental Oceanographic Commission
Technical Series
142

Users' Guide for the Northwest Pacific Tsunami Advisory Center (NWPTAC)

Enhanced Products for the Pacific Tsunami Warning System

UNESCO 2019

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(IOC/2019/TS/142)

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Executive Summary

Since 2005, the Northwest Pacific Tsunami Advisory Center (NWPTAC) of the Japan Meteorological Agency (JMA) has implemented Northwest Pacific Tsunami Advisory (NWPTA) services for Northwest Pacific countries in its role as a sub-regional Tsunami Service Provider (TSP) for the Pacific Tsunami Warning and Mitigation System (PTWS).

Following the successful launch of the Pacific Tsunami Warning Center (PTWC) Enhanced Products and a series of recommendations given by the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS), NWPTAC worked to enhance its existing products in order to provide recipient countries with improved products via detailed tsunami threat assessments for local coastal areas. Upon approval from the PTWS Steering Committee, NWPTAC started email issuance of the enhanced products on an experimental phase as from 20 December 2017, in parallel with its existing products. This introduction and familiarization period was intended to support training on the new products and recipient country implementation of the necessary Standard Operating Procedure (SOP) updates.

This users' guide describes NWPTAC Enhanced Products and provides related examples. In addition to text-based products, additional graphical products with more information and much greater levels of detail will also be available. These include maps showing deep-ocean tsunami amplitude forecasts, tsunami travel time forecasts and expected maximum wave amplitudes in coastal areas.

1. OVERVIEW

1.1 INTRODUCTION

The successful launch of the Pacific Tsunami Warning Center (PTWC) Enhanced Products in October 2014 demonstrated the mature capacity of Member States to utilize advanced graphical products. This prompted the Japan Meteorological Agency (JMA) to consider providing Northwest Pacific Tsunami Advisory Center (NWPTAC) Enhanced Products along with additional graphical information to meet user requirements. As the output of graphical products requires advanced tsunami forecasting capacity, JMA decided to take steps to add real-time simulation to its existing database-driven predictions.

In recognition of the importance of providing concise, easy-to-understand conventional text messages containing information on forecast amplitudes for selected individual Forecast Points (FPs), JMA decided to continue to issue its existing text products in conjunction with the graphical products.

Annex II lists the FPs for which data are reported in NWPTAC products. The list has been modified in consideration of those used for PTWC products and based on user countries' requests.

To avoid public confusion, NWPTAC products are provided exclusively to national authorities responsible for domestic tsunami alerts in NWPTAC's Area of Service (AoS).

1.2 GOVERNANCE AND APPROVAL

Since 1978, in-depth discussions have been held by the International Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/ITSU, now renamed ICG/PTWS) on the establishment of regional tsunami warning centres to issue tsunami advisories tailored to individual Pacific regions. At the 14th session of the ICG/ITSU held in Tokyo, Japan, from 30 August to 3 September 1993 (IOC/ITSU-XIV), the Republic of Korea proposed that JMA operates such a centre for the Northwest Pacific region.

The ICG/ITSU, at its 17th session (IOC/ITSU-XVII/3) held from 4 to 7 October 1999 in Seoul, Republic of Korea, approved JMA's proposal to establish a regional tsunami warning centre for the Northwest Pacific. At the 19th session of the ICG/ITSU (IOC/ITSU-XIX/3) held from 29 September to 2 October 2003 in Wellington, New Zealand, JMA reported on its readiness for the centre's operation. In 2004, the Executive Council (EC) of the Intergovernmental Oceanographic Commission (IOC) at its 37th session held from 23 to 29 June 2004 in Paris (IOC/EC-XXXVII/3) adopted resolution EC-XXXVII.4 to start the services of the regional centre at JMA by March 2005.

Based on such international consensus, JMA initiated the operation of the regional centre within the Tsunami Forecast Center at its headquarters in March 2005 to provide tsunami advisory services to the Northwest Pacific. At the 20th session of the ICG/ITSU (IOC/ITSU-XX/3) held in Viña del Mar, Chile, from 3 to 7 October 2005, JMA reported on the inauguration of NWPTAC. At the same session, the Group asked JMA to also provide interim tsunami advisory services for the South China Sea region. JMA upgraded its system and began the service in April 2006, following the endorsement of the Executive Council at its 39th session (IOC/EC-XXXIX/3) held from 21 to 28 June 2006 in Paris.

The ICG/PTWS at its 22nd session (ICG/PTWS-XXII/3s) held in Guayaquil, Ecuador, from 17 to 21 September 2007, began the process of improving PTWS international alert products starting with PTWC products. At its 24th session (ICG/PTWS-XXIV/3) held in Beijing, China, from 24 to 27 May 2011, the ICG/PTWS accepted a PTWC proposal for Enhanced Tsunami

Products. After approval of the final products and the proposed target changeover date at the 25th session (ICG/PTWS-XXV), that took place from 9 to11 September 2013 in Vladivostok, Russian Federation, PTWC began issuing its new enhanced products in October 2014.

In pursuit of improvement for PTWS tsunami warning products Japan announced, at the 47th session of the Executive Council (IOC/EC-XLVII/3) held from 1 to 4 July 2014 in Paris, that NWPTAC would also be developing new products based on the requirements of user countries. The PTWS Steering Committee (SC) met later in the same month and agreed on a timeline targeting full transition to NWPTAC Enhanced Products. It also recommended that JMA continue the process of developing NWPTAC Enhanced Products for PTWS.

At the 26th session (ICG/PTWS-XXVI/3) held from 22 to 24 April 2015 in Honolulu, United States of America, the ICG/PTWS agreed that NWPTAC should proceed with its development of enhanced products for the Northwest Pacific region. Accordingly, Exercise Pacific Wave 2016 (PacWave16, IOC/2015/TS/126 VOL.1, VOL.2) and Exercise Pacific Wave 2017 (PacWave17, IOC/2016/TS/131 VOL.1, VOL.2) were conducted in 2016 and 2017, respectively, to evaluate NWPTAC Enhanced Products.

The ICG/PTWS agreed at the 27th session (ICG/PTWS-XXVII) held from 28 to 31 March 2017 in Tahiti, French Polinesia, that NWPTAC should start the issuance of its experimental NWPTAC Enhanced Products in parallel with its existing products in the second half of 2017.

1.3 IMPLEMENTATION TIMELINE

To support the transition to the new products, PTWS organized two international exercises in 2016 and 2017.

PacWave16 (1–5 February 2016) served to introduce the proposed products and allow for feedback on their format and content. This feedback was considered in the development of the final products. For more on PacWave16, see:

http://itic.ioc-unesco.org/index.php?option=com_content&view=category&id=2168&Itemid=2642.

PacWave17 (15–17 February 2017) to allow evaluation of Member States' interpretation of the new products accurately and in a timely manner. For more on PacWave17, see:

http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2222&Itemid=2734.

The SC Task Team on PacWave Exercises oversaw the planning, execution and post-exercise evaluation of the new products and worked with PTWS WG2 Task Team on enhancing products for successful implementation.

At the 27th session of the ICG/PTWS held from 28 to 31 March 2017 in Tahiti, French Polinesia, Member States endorsed the Northwest Pacific Tsunami Advisory Center's plan to begin issuing in experimental mode its new NWPTAC Enhanced products in 2017. After the confirmation of the starting date by SC, JMA started issuing experimental NWPTAC Enhanced Products on 20 December 2017.

The ICG/PTWS also decided at this session a targeted change-over date around one half to one year from the experimental NWPTAC Enhanced Products provision for the official full switchover to the new products. After the one year experimental term including Exercise Pacific Wave 2018 (IOC/2018/TS/139 VOL.1 REV.2), JMA will changeover fully to NWPTAC Enhanced Products on 28 February 2019.

2. AREA OF SERVICE AND CRITERIA FOR ISSUANCE

- NWPTA information is issued when NWPTAC detects an earthquake of magnitude 6.5 or more in its AoS (see Figure 1), which covers the North-western Pacific and a portion of its South-western part as well as the South China Sea region on an interim basis.

- Data from tsunami observation reports received by NWPTAC are included in subsequent NWPTA messages as necessary.

- If the Centroid Moment Tensor (CMT) solution becomes available after the above NWPTA is issued, NWPTA based on real-time simulation are provided. The graphical products are provided only when tsunami amplitude of 0.3 m or more is expected for any FP.

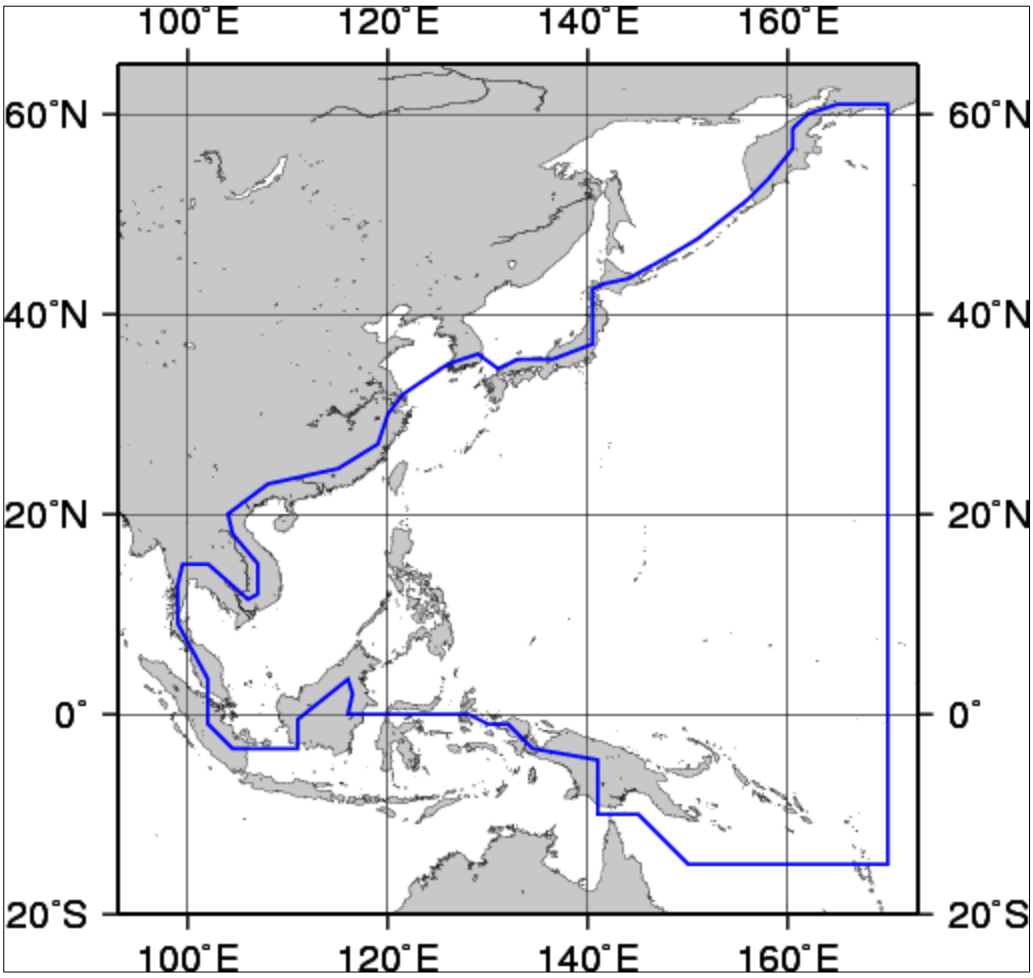

Figure 1. NWPTA Area of Service (AoS)

3. NWPTAC ENHANCED PRODUCTS

3.1 OUTLINE OF NWPTAC ENHANCED PRODUCTS

NWPTAC Enhanced Products consist of initial text messages compiled from a pre-established tsunami simulation database and subsequent text messages accompanied by graphical products based on real-time simulation techniques. The products will be distributed exclusively to national authorities of user countries.

The product specifications are as follows:

a. Text products

- Forecast method
  - First message (and second message in the event of an earthquake parameter update) from tsunami forecast database using preliminary determined hypocentre and magnitude.
  - Subsequent messages from real-time simulation using the CMT solution.
- Contents
  - Earthquake parameters (origin time, location, magnitude)
  - Tsunamigenic potential
  - Coastal blocks
  - Forecast amplitude and arrival time
  - Observed amplitude and arrival time
  - Distribution channels
  - GTS, fax, e-mail

b. Graphical products (maps)

- Forecast method
  - Real-time simulation
- Contents
  - Deep-ocean tsunami amplitude forecast map
  - Tsunami travel time map
  - Coastal tsunami amplitude forecast map
- Distribution channels
  - E-mail

Annex I provides examples of NWPTAC Enhanced Products.

3.2 TEXT PRODUCTS

3.2.1 Earthquake Information

a. Origin time

b. Epicentre coordinates (latitude and longitude)

c. Location (geographical area)

d. Depth (for earthquakes occurring at depths of 100 km or more)

e. Magnitude (JMA Magnitude, Moment Magnitude or Magnitude by PTWC/USGS)

REFERENCE

UNESCO/IOC. 2011. *Operational Users Guide for the Pacific Tsunami Warning and Mitigation System (PTWS)*. Paris, UNESCO, Technical Series No. 87, Second Edition (Annex II).

3.2.2 Tsunamigenic Potential

Tsunamigenic potential is evaluated from earthquake magnitude as follows:

M6.5 – 7.0: Very small possibility of a destructive local tsunami

M7.1 – 7.5: Possibility of a destructive local tsunami near the epicentre

M7.6 – 7.8: Possibility of a destructive regional tsunami

M7.9 – : Possibility of a destructive ocean-wide tsunami

No tsunamigenic potential is associated with earthquakes occurring inland or at depths of 100 km or more.

3.2.3 Tsunami Estimated Amplitude and Arrival Time

A tsunami amplitude and an arrival time are estimated for each FP in coastal areas (Annex II). This information is listed in NWPTA messages with the names of FPs and their latitudes/longitudes (to the nearest 0.1 degrees) in coastal-block groups.

Amplitude here is defined as the maximum distance between the crests of tsunami waves and the undisturbed sea level. Estimated tsunami amplitude is indicated only for FPs where tsunami of 0.3 m or more is expected to reach. The classifications are 0.3 – 1 m, 1 – 3 m, 3 – 5 m, 5 – 10 m and over 10 m. When tsunami amplitude of less than 0.3 m is estimated for all FPs, NWPTA message states “Estimation at forecast points – no tsunami waves with an amplitude of 0.3 meters or more are expected at any forecast point.”

3.2.4 Tsunami Observation

Information on the amplitude of the largest wave (to the nearest 0.1 m) and other data on tsunami waves observed at tidal stations with telemetric links to NWPTAC are provided as necessary.

3.3 GRAPHICAL PRODUCTS

Location (Lat./Lon.), depth (if indicated) and magnitude values indicated in the graphical products are the same ones in the text product. Magnitude value is revaluated by the CMT analysis.

3.3.1 Tsunami Travel Time Map

This shows the estimated travel time based on the earthquake location and magnitude determined.

Limitations

Actual arrival times may differ from forecast times for reasons including:

- Tsunami source uncertainty (The area of seafloor deformation is assumed from earthquake location and magnitude.)
- Bathymetry uncertainty around the observation point and elsewhere.
- Nonlinear effects on tsunami propagation that are not considered in travel time estimation (Such effects may be more significant in shallow water.)
- Difficulty of determining first-wave arrival times from sea level observation data.

3.3.2 Coastal Tsunami Amplitude Forecast Map

This shows individual coastal points with coloring based on the forecast tsunami amplitude at each point.

The greater of two forecast amplitudes based on a conjugate fault set determined via CMT analysis is used for each point.

Limitations

Actual coastal amplitudes may differ from forecasts for reasons including:

- Tsunami source uncertainties (Two rectangular faults are assumed from CMT analysis.)
- Uncertainties regarding tsunami/coastal interaction (Green's Law is used as a general approximation.)

Results can easily vary by a factor of two due to these uncertainties.

3.3.3 Deep-Ocean Tsunami Amplitude Forecast Map

This shows the maximum tsunami amplitude at each place in the deep ocean.

It shows how the tsunami is (i) directed away from the tsunami source, (ii) focused and defocused by the shape of the seafloor, and (iii) dissipated due to spreading.

Two maps based on a conjugate fault set determined via CMT analysis are provided.

Limitations

Actual deep-ocean tsunami amplitudes may differ from forecasts due to tsunami source uncertainties (two rectangular faults are assumed from CMT analysis) and other factors.

This map should not be used to estimate coastal tsunami amplitudes or impacts.

3.4 PRODUCT ISSUANCE TIMELINE

The timeline of NWTPA issuance shown below (Table 1) is typical but approximate and conservative.

NWTPA issuance timeline	
00 h 00 m	A large earthquake occurs in the Northwest Pacific region.
00 h 10 m	NWPTAC receives an initial text product from PTWC.
00 h 30 m	**The first NWPTAC text product** based on information from a tsunami forecast database is issued along with data on preliminary earthquake parameters consistent with those in the initial PTWC message.
00 h 40 m	The CMT solution is obtained and real-time simulation is started.
00 h 50 m	Real-time simulation is completed.
01 h 00 m	**The second NWPTAC text product** and **graphical products** based on real-time simulation are issued.

Table 1. Product issuance timeline by NWTPA

4. DISTRIBUTION CHANNELS

NWPTAs are provided via the GTS with the heading of WEPA40 RJTD and by e-mail and fax. Users are strongly advised to adopt multiple communication channels in order to ensure receipt.

5. COMMUNICATIONS TEST

NWPTAC conducts communications test approximately twice a year on links to user organizations. Advance notice of test is provided via an IOC Circular Letter. In the test, users are asked to acknowledge receipt of a test message using a reporting form provided with e-mail, fax and the Circular Letter.

6. STATUS OF NWPTAC PRODUCTS

NWPTAC Enhanced Products are provided alongside PTWC tsunami products to support user countries in taking timely and appropriate action against tsunami threats. However, it is important to note that the products are simply advisories to support user countries' efforts in alerting people to hazards; the actual issuance of evacuation notices is the responsibility of the countries themselves. The accuracy of tsunami amplitude/arrival estimation times in the products and the timing of forecast issuance depend on the availability of seismic data and the technology used for hypocentre/CMT determination and quantitative tsunami forecasting. Accordingly, user countries are strongly advised to optimize their use of NWPTAC products with careful consideration of the technological background as described in this Users' Guide.

NWPTAC makes every effort to provide its products as quickly as possible. However, people may need to be alerted in advance of NWPTA issuance in the event of large earthquakes in coastal areas, as tsunamis may reach land quickly.

NWPTAC products do not refer to the lifting of warnings in subsequent issues because NWPTAC itself does not issue warnings. These should be officially issued and lifted by the authorities of the countries concerned, as tsunami characteristics depend on coastal terrain.

In the event of any difference in tsunami severity evaluation between PTWC and NWPTAC products, the severer one should be adopted.

JMA's NWPTA operation system is duplicated in case of partial malfunction. However, the possibility of catastrophic failure cannot be eliminated. If NWPTA products are not issued in an emergency, NWPTA user countries/organizations should take appropriate action with reference to PTWC products.

7. NWPTA TEMPLATE

This section details NWPTAC text product, which is based on the following template:

WEPA40 RJTD ***DDhhmm***	<--- (1)
TSUNAMI BULLETIN NUMBER ***NNN*** ISSUED BY NWPTAC(JMA) ISSUED AT ***hhmm***Z ***DD MMM YYYY*** PART ***nn*** OF ***NN*** PARTS	<--- (2)
HYPOCENTRAL PARAMETERS ORIGIN TIME:***hhmm***Z ***DD MMM YYYY*** PRELIMINARY EPICENTER:LAT***LL.L*{NORTH/SOUTH}** LON***LLL.L***EAST ***Geographical Area (Regional Scale)*** ***Geographical Area (Wider Scale)*** **[FOCAL DEPTH:*XXX*KM]** MAG:***M.M*** **[(MJMA)/(MW)]** **[BY PTWC]**	<--- (3)
EVALUATION ***Tsunamigenic Potential***	<--- (4)
THIS BULLETIN IS FOR ***Coastal Block-1*** ***Coastal Block-2*** ***...***	<--- (5)
ESTIMATED TSUNAMI ARRIVAL TIMES AND WAVE AMPLITUDES ***Coastal Block-1*** LOCATION COORDINATES ARRIVAL TIME AMPL ***FP-1*** ***LL.L*{N/S} *LLL.L***E ***hhmm***Z ***DD MMM AMPL*** ***Coastal Block-2*** LOCATION COORDINATES ARRIVAL TIME AMPL ***FP-2*** ***LL.L*{N/S} *LLL.L***E ***hhmm***Z ***DD MMM AMPL*** ***FP-3*** ***LL.L*{N/S} *LLL.L***E ***hhmm***Z ***DD MMM AMPL*** ***FP-4*** ***LL.L*{N/S} *LLL.L***E ***hhmm***Z ***DD MMM AMPL*** ***...*** AMPL – MAXIMUM AMPLITUDE IN METERS FROM THE UNDISTURBED SEA LEVEL TO THE CREST ***Remarks***	<--- (6)
MEASUREMENTS OR REPORTS OF TSUNAMI LOCATION COORDINATES ARRIVAL TIME AMPL ***STATION-1*** ***LL.L*{N/S} *LLL.L***E MAXIMUM TSUNAMI WAVE ***hhmm***Z ***DD MMM*** ***OBS***M ***STATION-2*** ***LL.L*{N/S} *LLL.L***E MAXIMUM TSUNAMI WAVE ***hhmm***Z ***DD MMM*** ***OBS***M ***...*** MAXIMUM TSUNAMI WAVE -- HALF THE AMPLITUDE FROM THE TROUGH TO THE CREST ***Remarks***	<--- (7)

Italic parts (***DDhhmm***, etc.) indicate that numbers or sentences are described in accordance with the following explanation.

Braces (**{NORTH/SOUTH}**, etc.) indicate that one of the words divided by slashes is described.

Brackets (**[(MJMA)/(MW)]**, etc.) indicate that the word (or one of the words divided by slashes) is optional.

7.1 HEADING

The heading of messages on the GTS circuit (WEPA40 RJTD) appears at the top. ***DDhhmm*** represents the day, hour and minute of issuance in UTC.

7.2 BULLETIN NUMBER

NNN is the number of the bulletin, and increases with each issuance.

hhmm, ***DD***, ***MMM*** and ***YYYY*** represent the hour, minute, day, month and year of issuance in UTC. Overly long NWPTA messages may be issued in separate parts.

nn is the number of the part, and ***NN*** is the total number of parts. For non-separated messages, ***nn*** and ***NN*** are both 01.

7.3 EARTHQUAKE PARAMETERS

This part contains the following items:

- Origin time
- Epicentre coordinates (latitude and longitude)
- Location (geographical area)
- Depth (for earthquakes occurring at depths of 100 km or more)
- Magnitude (JMA Magnitude, Moment Magnitude or Magnitude by PTWC/USGS)

hhmm, ***DD***, ***MMM*** and ***YYYY*** represent the hour, minute, day, month and year of the earthquake's origin in UTC. ***LL.L*** and ***LLL.L*** represent the latitude and longitude of the epicentre, respectively. **NORTH** or **SOUTH** is added for latitude, while the longitude is always EAST. ***Geographical Area*** is the epicentre region based on Flinn-Engdahl regionalization[1]. ***M.M*** is the magnitude of the earthquake. **(MJMA)** is added for Mjma values and **(MW)** is added for Moment Magnitude values. **FOCAL DEPTH** is included only for depths of 100 km or more. When parameters are revised in a subsequent message, **(REVISION)** appears on the first line of this part.

To ensure consistency and minimize confusion among users, NWPTAC and PTWC coordinate their earthquake parameters prior to official bulletin issuance using agreed-upon arrangements, and use identical earthquake parameters in their first text products to the maximum extent possible. When NWPTAC use the earthquake parameters by PTWC, **BY PTWC** is added at the end of this part.

7.4 TSUNAMIGENIC POTENTIAL

Tsunamigenic potential evaluation is based on earthquake magnitude as follows:

[1] See also https://earthquake.usgs.gov/learn/topics/flinn_engdahl.php.

Criteria	Tsunamigenic potential
Inland or deep undersea (100 km –) NW Pacific event in AoS, M6.5 –	No possibility of a tsunami
Shallow undersea NW Pacific event in AoS, M6.5 – 7.0	Very small possibility of a destructive local tsunami
Shallow undersea NW Pacific event in AoS, M7.1 – 7.5	Possibility of a destructive local tsunami near the epicentre
Shallow undersea NW Pacific event in AoS, M7.6 – 7.8	Possibility of a destructive regional tsunami
Shallow undersea NW Pacific event in AoS, M7.9 –	Possibility of a destructive ocean-wide tsunami

Table 2. NWPTAC criteria for tsunamigenic potential evaluation

7.5 COASTAL BLOCKS

If a tsunami with an amplitude of 0.3 m or more is expected for any FP, the ***Coastal Block***s containing the relevant FPs are shown in this part (Annex II). If no tsunami of this scale is expected at any FP, the report states, **ESTIMATION AT FORECAST POINTS - NO TSUNAMI WAVES WITH AN AMPLITUDE OF 0.3 METERS OR MORE ARE EXPECTED AT ANY FORECAST POINT. (Addition)** or **(Cancellation)** is specified as described below (Section 7.6) in subsequent information issued due to earthquake parameter updates.

7.6 FORECAST AMPLITUDE AND ARRIVAL TIME

Tsunami amplitude and arrival time are estimated for each coastal FP. The estimated amplitudes (***AMPL***) and arrival times (***hhmm DD MMM*** in UTC) are listed with the names (***FP-1***, etc.) for each FP along with its latitude and longitude (***LL.L*****{N/S}** ***LLL.L***E to the nearest 0.1 degrees) in ***Coastal-Block*** groups.

Amplitude here is defined as the maximum distance between the crests of tsunami waves and the undisturbed sea level. It is estimated in categories of **0.3–1M**, **1–3M**, **3–5M**, **5–10M** and **OVER10M**, and shown only for FPs expected to experience tsunami with heights of 0.3 m or more. If no tsunami of this scale is expected at any FP, this part does not appear in the message.

If new FPs need to be added or the expected arrival time/amplitude of tsunami need to be changed in a revised issue due to earthquake parameter updates, **(Addition)** or **(Revision)** is specified in the line for the relevant FPs. For FPs that appeared in the previous NWPTA message but need to be removed due to revision, **(Cancellation)** is stated in the revised issuance.

7.7 TSUNAMI OBSERVATION

Information on tsunami waves recorded at sea level stations with telemetric links to NWPTAC is provided as necessary. The amplitude (***OBS***) of the largest wave to the nearest 0.1 m and the arrival time (***hhmm DD MMM*** in UTC) are listed along with the station name (***STATION-1***, etc.) and its latitude and longitude (***LL.L*****{N/S}** ***LLL.L***E to the nearest 0.1 degrees).

To minimize confusion among user countries/organizations, NWPTAC generally adopts values of Maximum Tsunami Amplitude in PTWC products in correspondence to those in NWPTAC products.

7.8 QUALITATIVE EXPRESSIONS FOR HUGE EARTHQUAKES

In the event of a huge earthquake close to Japan, the qualitative forecast amplitude expression **Huge**, **High** or **----** and the magnitude expression **OVER 8** and **THIS INFORMATION IS BASED ON THE PREDEFINED MAGNITUDE** may be used in NWPTAs. Such expressions can be shown when the earthquake is so massive that JMA magnitude is unavailable, and moment magnitude is undetermined within around 15 minutes as well. In such cases, tsunami scale estimation is based on a predefined possible maximum magnitude.

8. FORECAST MODEL

8.1 TSUNAMI FORECAST DATABASE

JMA uses a tsunami forecast system in conjunction with a numerical simulation technique for quantitative tsunami warnings. Tsunami propagation scenarios based on various fault types/locations were simulated in advance, and data on calculated tsunami arrival times and amplitudes were stored in a database along with information on magnitudes and hypocenter locations. The presumed epicenter locations are shown in Figure 2. For each one, faults with four magnitudes (M8.5, 8.0, 7.5 and 7.0) and six depths (0, 20, 40, 60, 80 and 100 km) are determined. Once an earthquake occurs and its hypocentre and magnitude are determined, the nearest scenario is retrieved for NWPTA formulation. Specifically, the scenario with the closest fault location is selected, and tsunami amplitudes are estimated via interpolation or extrapolation relating to magnitude and depth. For tsunami propagation simulation, the model described in 8.2 is used.

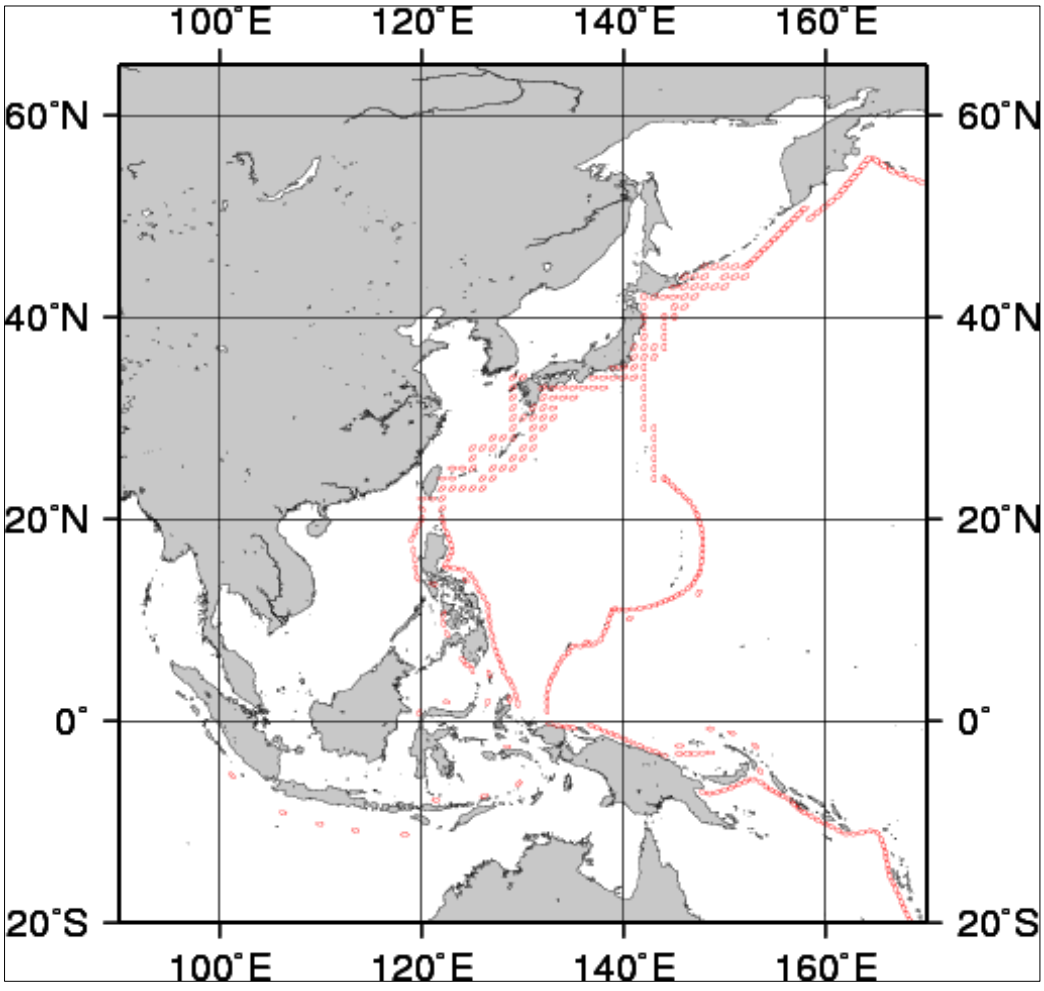

Figure 2. Assumed fault locations for NWPTAC tsunami forecast database

8.2 NUMERICAL SIMULATION

In the calculation of tsunami propagation for tsunami forecast database information and real-time forecasting, JMA uses a numerical tsunami simulation model based on the non-linear long wave theory. This model incorporates the effects of Coriolis force and sea floor friction, and has a grid resolution of 1 arc-min (e.g., Satake, 2002).

The long wave theory can be applied when the wavelength of a tsunami is considered to significantly exceed the sea depth and when the wave amplitude is considered to be much less than the sea depth. However, these conditions are not applicable for tsunamis heading toward coastal areas in shallow water. Hence, estimation of tsunami amplitudes at coastal points is based on the simulated value for a corresponding offshore point several to several tens of kilometers offshore using Green's Law (e.g., Satake, 2002) as described below.

$$A_{coast} = A_{offshore}\left(D_{offshore}/D_{coast}\right)^{1/4}$$

Here:

A_{coast} : Tsunami amplitude at coast

$A_{offshore}$: Tsunami amplitude at offshore grid point

$D_{offshore}$: Ocean depth at offshore grid point

D_{coast} : Ocean depth at coast

The coastal ocean depth is set to be 1 m.

Meanwhile, the tsunami arrival time at the offshore point as determined from numerical simulation is regarded as that at the corresponding coastal point without conversion. The arrival time is defined as the point at which the estimated amplitude initially exceeds 5 cm.

It should be noted that actual tsunami arrival times and amplitudes may differ from predictive data depending on coastal and sea bed topography, especially in coastal areas where fine-mesh bathymetric data are not used in numerical simulation for tsunamis. Accordingly, although estimated arrival times for each FP are given to the nearest minute, data are not necessarily accurate to the order of a minute. Tsunamis may arrive earlier or later than NWPTA estimated times.

Reference

Satake, K. 2002. Tsunamis. *International Handbook of Earthquake & Engineering Seismology*, Part A, III-28. Academic Press.

8.3 TSUNAMI TRAVEL TIMES

Calculation of tsunami travel times shown on Tsunami Travel Time Maps is based on the long wave theory, meaning that wave speed is computed from the square root of the quantity water depth multiplied by the acceleration of gravity. Accordingly, times shown on these maps may not precisely match the times in NWPTA text messages.

ANNEX I

EXAMPLES OF NWPTAC ENHANCED PRODUCTS

a. First Text Product (when coastal tsunami with heights of 0.3 m or more are expected)

```
WEPA40 RJTD 240919

TSUNAMI BULLETIN NUMBER 001
   ISSUED BY NWPTAC(JMA)
   ISSUED AT 0919Z 24 MAR 2018
PART 01 OF 01 PARTS

HYPOCENTRAL PARAMETERS
ORIGIN TIME:0858Z 24 MAR 2018
PRELIMINARY EPICENTER:LAT03.0SOUTH LON148.0EAST
 BISMARCK SEA
 NEW GUINEA AREA
MAG:8.2
BY PTWC

EVALUATION
 THERE IS A POSSIBILITY OF A DESTRUCTIVE OCEAN-WIDE TSUNAMI

THIS BULLETIN IS FOR
NORTH COASTS OF IRIAN JAYA
NORTH COASTS OF PAPUA NEW GUINEA
CELEBES SEA

ESTIMATED TSUNAMI ARRIVAL TIMES AND WAVE AMPLITUDES
NORTH COASTS OF IRIAN JAYA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 MANOKWARI             00.8S 134.2E 1116Z 24 MAR  1-3M
 WARSA                 00.6S 135.8E 1046Z 24 MAR  1-3M
 JAYAPURA              02.4S 140.8E 1002Z 24 MAR  1-3M
NORTH COASTS OF PAPUA NEW GUINEA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 VANIMO                02.6S 141.3E 0953Z 24 MAR  1-3M
 WEWAK                 03.5S 143.7E 0931Z 24 MAR  3-5M
 MADANG                05.2S 145.8E 0935Z 24 MAR  5-10M
 MANUS_IS.             02.0S 147.5E 0858Z 24 MAR  3-5M
 RABAUL                04.2S 152.3E 1000Z 24 MAR  OVER10M
CELEBES SEA
 LOCATION            COORDINATES  ARRIVAL TIME  AMPL
 MANADO              01.6N 124.9E 1304Z 24 MAR  1-3M

AMPL - MAXIMUM AMPLITUDE IN METERS FROM THE
UNDISTURBED SEA LEVEL TO THE CREST

IN SOME COASTAL AREAS (PARTICULARLY NEAR THE EPICENTER),
TSUNAMI WAVES MAY BE HIGHER AND/OR ARRIVE EARLIER THAN
ESTIMATED FOR NEARBY FORECAST POINTS.
AUTHORITIES SHOULD BE AWARE OF THIS POSSIBILITY.

THE EVALUATION OF TSUNAMIGENIC POTENTIAL AND ESTIMATED
ARRIVAL TIMES FOR TSUNAMI WAVES MAY ALSO DIFFER FROM
THOSE OF PTWC DUE TO DIFFERENCES IN ESTIMATED EARTHQUAKE
PARAMETERS AND THE TSUNAMI FORECAST MODEL.
AUTHORITIES SHOULD REFER TO EARLIER ARRIVAL TIMES
FOR GREATEST SAFETY.

THIS WILL BE THE FINAL BULLETIN UNLESS CHANGES IN THE POTENTIAL
FOR TSUNAMI GENERATION ARE DEEMED POSSIBLE BASED ON EARTHQUAKE
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RE-EVALUATION OR REPORTS INDICATING TSUNAMI OBSERVATION ARE
RECEIVED.
```

b. First Text Product (when coastal tsunami with heights of 0.3 m or more are not expected)

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WEPA40 RJTD 102308

TSUNAMI BULLETIN NUMBER 001
   ISSUED BY NWPTAC(JMA)
   ISSUED AT 2308Z 10 MAR 2018
PART 01 OF 01 PARTS

HYPOCENTRAL PARAMETERS
ORIGIN TIME:2252Z 10 MAR 2018
PRELIMINARY EPICENTER:LAT38.0NORTH LON142.9EAST
 NEAR EAST COAST OF HONSHU, JAPAN
 JAPAN - KURIL ISLANDS - KAMCHATKA PENINSULA
MAG:6.7 (MJMA)

EVALUATION
 THERE IS A VERY SMALL POSSIBILITY OF A DESTRUCTIVE LOCAL TSUNAMI

ESTIMATION AT FORECAST POINTS - NO TSUNAMI WAVES WITH AN AMPLITUDE
OF 0.3 METERS OR MORE ARE EXPECTED AT ANY FORECAST POINT.

HOWEVER, IN SOME COASTAL AREAS (PARTICULARLY NEAR THE EPICENTER),
HIGHER TSUNAMI WAVES THAN ESTIMATED MAY ARRIVE.
AUTHORITIES SHOULD BE AWARE OF THIS POSSIBILITY.

THIS WILL BE THE FINAL BULLETIN UNLESS CHANGES IN THE POTENTIAL
FOR TSUNAMI GENERATION ARE DEEMED POSSIBLE BASED ON EARTHQUAKE
RE-EVALUATION OR REPORTS INDICATING TSUNAMI OBSERVATION ARE
RECEIVED.
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c. First Text Product (when Mjma is judged as underestimated and M_w is unavailable in a timely manner)

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WEPA40 RJTD 240919

TSUNAMI BULLETIN NUMBER 001
   ISSUED BY NWPTAC(JMA)
   ISSUED AT 0919Z 24 MAR 2018
PART 01 OF 01 PARTS

HYPOCENTRAL PARAMETERS
ORIGIN TIME:0858Z 24 MAR 2018
PRELIMINARY EPICENTER:LAT38.0NORTH LON142.9EAST
 NEAR EAST COAST OF HONSHU, JAPAN
 JAPAN - KURIL ISLANDS - KAMCHATKA PENINSULA
MAG:OVER 8

THIS INFORMATION IS BASED ON THE PREDEFINED MAGNITUDE

EVALUATION
 THERE IS A POSSIBILITY OF A DESTRUCTIVE OCEAN-WIDE TSUNAMI

THIS BULLETIN IS FOR
EAST COASTS OF PHILIPPINES
NORTH COASTS OF IRIAN JAYA
CELEBES SEA

ESTIMATED TSUNAMI ARRIVAL TIMES AND WAVE AMPLITUDES
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EAST COASTS OF PHILIPPINES
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 LEGASPI               13.2N 123.8E 1257Z 24 MAR  ----
NORTH COASTS OF IRIAN JAYA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 MANOKWARI             00.8S 134.2E 1116Z 24 MAR  HIGH
 WARSA                 00.6S 135.8E 1046Z 24 MAR  HIGH
 JAYAPURA              02.4S 140.8E 1002Z 24 MAR  HUGE
CELEBES SEA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 MANADO                01.6N 124.9E 1304Z 24 MAR  ----

AMPL - MAXIMUM AMPLITUDE IN METERS FROM THE
UNDISTURBED SEA LEVEL TO THE CREST

IN SOME COASTAL AREAS (PARTICULARLY NEAR THE EPICENTER),
TSUNAMI WAVES MAY BE HIGHER AND/OR ARRIVE EARLIER THAN
ESTIMATED FOR NEARBY FORECAST POINTS.
AUTHORITIES SHOULD BE AWARE OF THIS POSSIBILITY.

THE EVALUATION OF TSUNAMIGENIC POTENTIAL AND ESTIMATED
ARRIVAL TIMES FOR TSUNAMI WAVES MAY ALSO DIFFER FROM
THOSE OF PTWC DUE TO DIFFERENCES IN ESTIMATED EARTHQUAKE
PARAMETERS AND THE TSUNAMI FORECAST MODEL.
AUTHORITIES SHOULD REFER TO EARLIER ARRIVAL TIMES
FOR GREATEST SAFETY.

THIS WILL BE THE FINAL BULLETIN UNLESS CHANGES IN THE POTENTIAL
FOR TSUNAMI GENERATION ARE DEEMED POSSIBLE BASED ON EARTHQUAKE
RE-EVALUATION OR REPORTS INDICATING TSUNAMI OBSERVATION ARE
RECEIVED.
```

d. First Text Product (when the depth is 100 km or more)

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WEPA40 RJTD 060505

TSUNAMI BULLETIN NUMBER 001
   ISSUED BY NWPTAC(JMA)
   ISSUED AT 0505Z 06 APR 2018
PART 01 OF 01 PARTS

HYPOCENTRAL PARAMETERS
ORIGIN TIME:0443Z 06 APR 2018
PRELIMINARY EPICENTER:LAT7.0NORTH LON138.0EAST
 W. CAROLINE ISLANDS, MICRONESIA
 CAROLINE ISLANDS TO GUAM
FOCAL DEPTH:120KM MAG:6.6
BY PTWC

EVALUATION
 THERE IS NO POSSIBILITY OF A TSUNAMI

THIS WILL BE THE FINAL BULLETIN UNLESS CHANGES IN THE POTENTIAL
FOR TSUNAMI GENERATION ARE DEEMED POSSIBLE BASED ON EARTHQUAKE
RE-EVALUATION OR REPORTS INDICATING TSUNAMI OBSERVATION ARE
RECEIVED.
```

e. Second Text Product (based on real-time simulation and added with tsunami observations)

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WEPA40 RJTD 240949

TSUNAMI BULLETIN NUMBER 002
   ISSUED BY NWPTAC(JMA)
   ISSUED AT 0949Z 24 MAR 2018
PART 01 OF 01 PARTS

HYPOCENTRAL PARAMETERS (REVISION)
ORIGIN TIME:0858Z 24 MAR 2018
PRELIMINARY EPICENTER:LAT03.0SOUTH LON148.0EAST
 BISMARCK SEA
 NEW GUINEA AREA
MAG:8.3 (MW)

EVALUATION
 THERE IS A POSSIBILITY OF A DESTRUCTIVE OCEAN-WIDE TSUNAMI

THIS BULLETIN IS FOR
EAST COASTS OF PHILIPPINES (ADDITION)
NORTH COASTS OF IRIAN JAYA
NORTH COASTS OF PAPUA NEW GUINEA
CELEBES SEA (CANCELLATION)

ESTIMATED TSUNAMI ARRIVAL TIMES AND WAVE AMPLITUDES
EAST COASTS OF PHILIPPINES
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 LEGASPI               13.2N 123.8E 1257Z 24 MAR  0.3-1M (ADDITION)
 DAVAO                 06.9N 125.7E 1237Z 24 MAR  0.3-1M (ADDITION)
NORTH COASTS OF IRIAN JAYA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 MANOKWARI             00.8S 134.2E 1116Z 24 MAR  0.3-1M (REVISION)
 WARSA                 00.6S 135.8E 1046Z 24 MAR  1-3M
 JAYAPURA              02.4S 140.8E 1002Z 24 MAR  1-3M
NORTH COASTS OF PAPUA NEW GUINEA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 VANIMO                02.6S 141.3E 0953Z 24 MAR  1-3M
 WEWAK                 03.5S 143.7E 0931Z 24 MAR  3-5M
 MADANG                05.2S 145.8E 0935Z 24 MAR  5-10M
 MANUS_IS.             02.0S 147.5E 0858Z 24 MAR  3-5M
 RABAUL                04.2S 152.3E 1000Z 24 MAR  OVER10M
CELEBES SEA
 LOCATION              COORDINATES  ARRIVAL TIME  AMPL
 MANADO                01.6N 124.9E (CANCELLATION)

AMPL - MAXIMUM AMPLITUDE IN METERS FROM THE
UNDISTURBED SEA LEVEL TO THE CREST

IN SOME COASTAL AREAS (PARTICULARLY NEAR THE EPICENTER),
TSUNAMI WAVES MAY BE HIGHER AND/OR ARRIVE EARLIER THAN
ESTIMATED FOR NEARBY FORECAST POINTS.
AUTHORITIES SHOULD BE AWARE OF THIS POSSIBILITY.

THE EVALUATION OF TSUNAMIGENIC POTENTIAL AND ESTIMATED
ARRIVAL TIMES FOR TSUNAMI WAVES MAY ALSO DIFFER FROM
THOSE OF PTWC DUE TO DIFFERENCES IN ESTIMATED EARTHQUAKE
PARAMETERS AND THE TSUNAMI FORECAST MODEL.
AUTHORITIES SHOULD REFER TO EARLIER ARRIVAL TIMES
FOR GREATEST SAFETY.

MEASUREMENTS OR REPORTS ON TSUNAMI
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```
 LOCATION                        COORDINATES ARRIVAL TIME  AMPL
 LEGASPI                         13.1N 123.8E
                          MAXIMUM TSUNAMI WAVE 0910Z 24 MAR  0.5M

MAXIMUM TSUNAMI WAVE -- HALF THE AMPLITUDE FROM THE TROUGH
TO THE CREST

THIS WILL BE THE FINAL BULLETIN UNLESS CHANGES IN THE POTENTIAL
FOR TSUNAMI GENERATION ARE DEEMED POSSIBLE BASED ON EARTHQUAKE
RE-EVALUATION OR REPORTS INDICATING TSUNAMI OBSERVATION ARE
RECEIVED.
```

f. Graphical Product

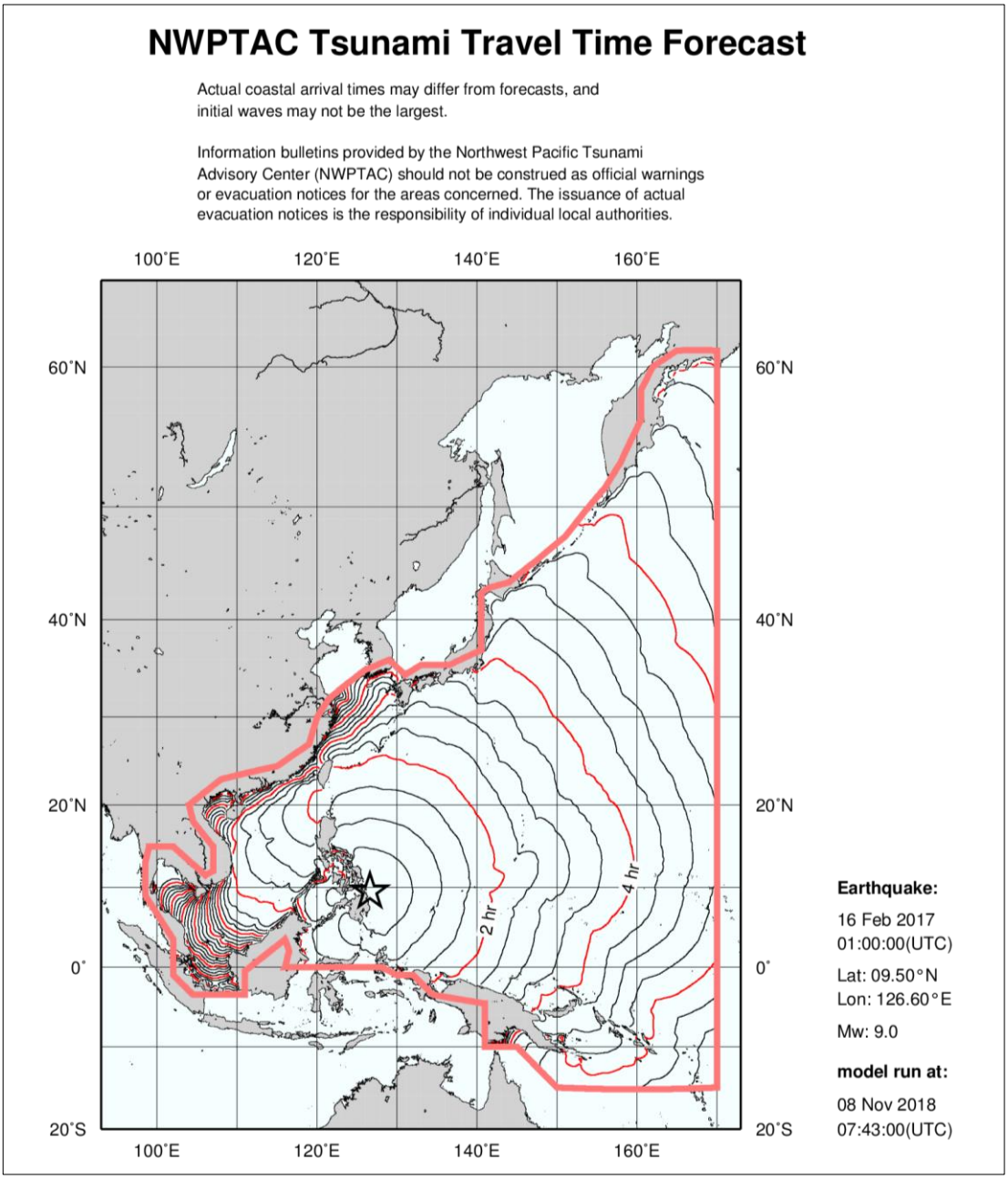


Image I-1. NWPTAC Tsunami Travel time Forecast

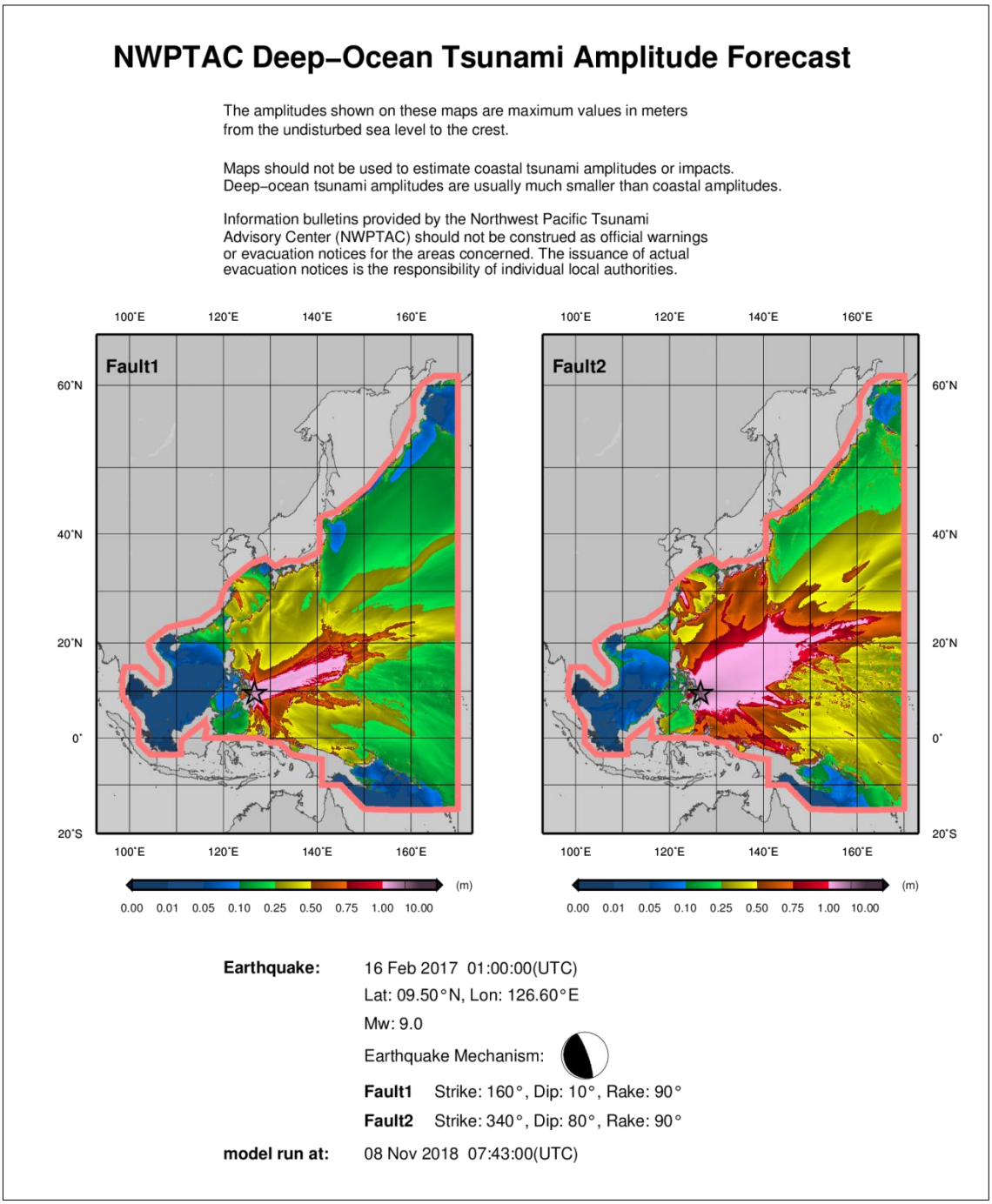


Image I-2. NWPTAC Deep-Ocean Tsunami Amplitude Forecast

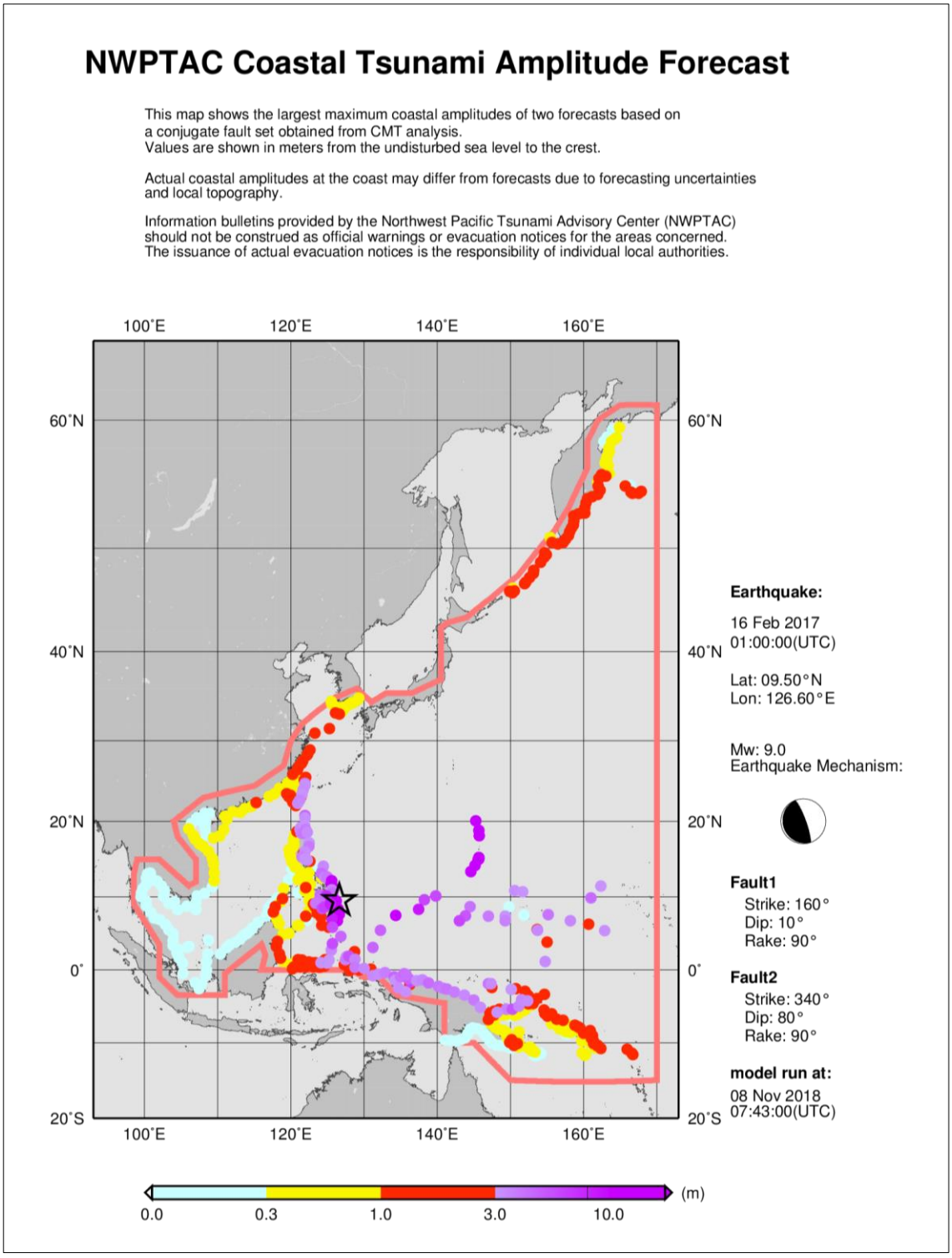


Image I-3. NWPTAC Coastal Tsunami Amplitude Forecast

ANNEX II

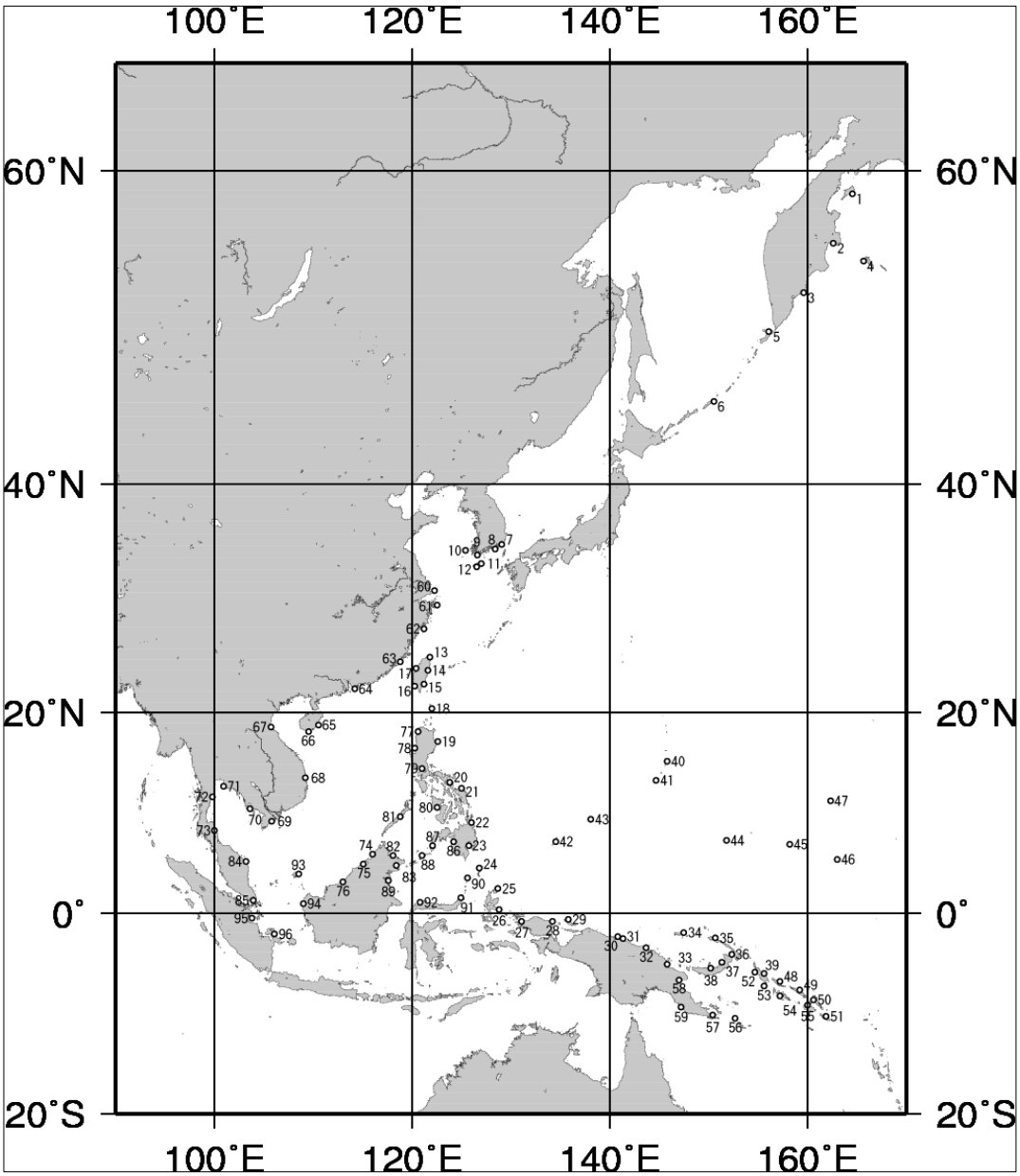
LIST OF FORECAST POINTS

Coastal Block	Forecast Point	Latitude	Longitude	FP Number
EAST COASTS OF KAMCHATKA PENINSULA	OSTROV_KARAGINSKIY	58.8N	164.5E	1
	UST_KAMCHATSK	56.1N	162.6E	2
	PETROPAVLOVSK_K	53.2N	159.6E	3
	NIKOLSKOYA	55.1N	165.7E	4
KURIL ISLANDS	SEVERO_KURILSK	50.8N	156.1E	5
	URUP_IS.	46.1N	150.5E	6
SOUTH COASTS OF KOREAN PENINSULA	BUSAN	35.1N	129.1E	7
	TONGYEONG	34.7N	128.4E	8
	NOHWA	34.2N	126.6E	9
	HEUKSANDO	34.6N	125.4E	10
	CHEJU_ISLAND	33.5N	127.0E	11
	SEOGWIPO	33.2N	126.5E	12
TAIWAN	CHILUNG	25.2N	121.8E	13
	HUALIEN	24.0N	121.6E	14
	TAITUNG	22.7N	121.2E	15
	KAOHSIUNG	22.5N	120.3E	16
	HOMEL	24.2N	120.4E	17
EAST COASTS OF PHILIPPINES	BASCO	20.4N	122.0E	18
	PALANAN	17.2N	122.6E	19
	LEGASPI	13.2N	123.8E	20
	LAOANG	12.6N	125.0E	21
	MADRID	09.2N	126.0E	22
	DAVAO	06.9N	125.7E	23
NORTH COASTS OF IRIAN JAYA	GEME	04.6N	126.8E	24
	BEREBERE	02.5N	128.7E	25
	PATANI	00.4N	128.8E	26
	SORONG	00.8S	131.1E	27
	MANOKWARI	00.8S	134.2E	28
	WARSA	00.6S	135.8E	29
	JAYAPURA	02.4S	140.8E	30
NORTH COASTS OF PAPUA NEW GUINEA	VANIMO	02.6S	141.3E	31
	WEWAK	03.5S	143.7E	32
NORTH COASTS OF PAPUA NEW GUINEA	MADANG	05.2S	145.8E	33
	MANUS_IS.	02.0S	147.5E	34
	KAVIENG	02.5S	150.7E	35
	RABAUL	04.2S	152.3E	36
	ULAMONA	05.0S	151.3E	37
	KIMBE	05.6S	150.2E	38
	KIETA	06.1S	155.6E	39
MARIANA ISLANDS	SAIPAN	15.3N	145.8E	40
	GUAM	13.4N	144.7E	41

Coastal Block	Forecast Point	Latitude	Longitude	FP Number
PALAU	MALAKAL	07.3N	134.5E	42
MICRONESIA	YAP_IS.	09.5N	138.1E	43
	CHUUK_IS.	07.4N	151.8E	44
	POHNPEI_IS.	07.0N	158.2E	45
	KOSRAE_IS.	05.5N	163.0E	46
MARSHALL ISLANDS	ENIWETOK	11.4N	162.3E	47
NORTH COASTS OF SOLOMON ISLANDS	PANGGOE	06.9S	157.2E	48
	GHATERE	07.8S	159.2E	49
	AUKI	08.8S	160.6E	50
	KIRAKIRA	10.4S	161.9E	51
SOLOMON SEA	AMUN	06.0S	154.7E	52
	FALAMAE	07.4S	155.6E	53
	MUNDA	08.4S	157.2E	54
	HONIARA	09.3S	160.0E	55
	MISIMA	10.6S	152.7E	56
	ALOTAU	10.3S	150.4E	57
	LAE	06.8S	147.0E	58
CORAL SEA	PORT_MORESBY	09.5S	147.2E	59
COASTS OF EAST CHINA SEA	SHANGHAI	31.2N	122.3E	60
	ZHOUSHAN	29.9N	122.5E	61
	WENZHOU	27.8N	121.2E	62
COASTS OF SOUTH CHINA SEA	QUANZHOU	24.8N	118.8E	63
	HONG_KONG	22.3N	114.2E	64
	HAINAN_ISLAND	18.8N	110.5E	65
COASTS OF SOUTH CHINA SEA	SANYA	18.2N	109.5E	66
COASTS OF GULF OF TONKIN	VINH	18.6N	105.7E	67
EAST COASTS OF	QUI_NHON	13.7N	109.2E	68
	BAC_LIEU	09.3N	105.8E	69
GULF OF THAILAND	SIHANOUKVILLE	10.6N	103.6E	70
	PATTAYA	12.8N	100.9E	71
	PRACHUAP_KHIRI_KHAN	11.8N	099.8E	72
	NAKHON_SI_THAMMARAT	08.4N	100.0E	73
NORTHWEST COASTS OF KALIMANTAN	KOTA_KINABALU	6.0N	116.0E	74
	MUARA	05.0N	115.1E	75
	BINTULU	03.2N	113.0E	76
WEST COASTS OF PHILIPPINES	LAOAG	18.2N	120.6E	77
	SAN_FERNANDO	16.6N	120.3E	78
	MANILA	14.6N	121.0E	79
SULU SEA	ILOILO	10.7N	122.5E	80
	PUERTO_PRINCESA	09.8N	118.8E	81
	SANDAKAN	05.9N	118.1E	82
	LAHAD_DATU	04.9N	118.4E	83
	KUALA_TERENGGANU	05.3N	103.2E	84

Coastal Block	Forecast Point	Latitude	Longitude	FP Number
EAST COASTS OF MALAY PENINSULA	SINGAPORE	01.3N	103.9E	85
CELEBES SEA	COTABUTO_CITY	07.3N	124.2E	86
	ZAMBOANGA	06.9N	122.1E	87
	MAIMBUNG	05.9N	121.0E	88
	TARAKAN	03.3N	117.6E	89
	TABUKAN_TENGAH	03.6N	125.6E	90
	MANADO	01.6N	124.9E	91
	TOLITOLI	01.1N	120.8E	92
NATUNA SEA	KEPULAUAN_RIAU	04.0N	108.5E	93
	SINGKAWANG	01.0N	109.0E	94
	KUALA_INDRAGIRI	00.5S	103.8E	95
	PANGKALPINANG	02.1S	106.1E	96

Figure II-1.Forecast points (FP) of NWPTAC Enhanced Products



ANNEX III

LIST OF ACRONYMS

AoS	Area of Service
CMT	Centroid Moment Tensor
EC	Executive Council
FP	Forecast Points
ICG/PTWS	Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System
IOC	Intergovernmental Oceanographic Commission (UNESCO)
JMA	Japan Meteorological Agency
NWPTA	Northwest Pacific Tsunami Advisory
NWPTA	Northwest Pacific Tsunami Advisory
NWPTAC	Northwest Pacific Tsunami Advisory Center
PTWC	Pacific Tsunami Warning Center
PTWS	Pacific Tsunami Warning and Mitigation System
SC	Steering Committee
SOP	Standard Operating Procedure
TSP	Tsunami Service Provider

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
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