Asian Disaster Reduction Center (ADRC)

Kobe, Japan

COMPARATIVE STUDY ON EARTHQUAKE AND TSUNAMI EARLY WARNING SYSTEM IN MALAYSIA AND JAPAN

A Research Study Report

For the Visiting Researcher - Asian Disaster Reduction Center

FY2018 (TERM A)

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Malaysian Meteorological Department (MMD)

Ministry of Energy, Science, Technology, Environment and Climate Change (MESTECC)

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DISCLAIMER

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ACKNOWLEDGEMENT

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Lastly, I would like extend my gratitude to all the persons who are involved either direct or indirect to complete this research study. Without their commitment and dedication, this study would not have materialized.

ACROYNM

AIST	National Institute of Advanced Industrial Science and Technology
AOR	Area of Responsible
ERI	Earthquake Research Institute, The University of Tokyo
GTS	Global Telecommunication System
GSI	Geospatial Information Authority of Japan
JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JCG	Japan Coast Guard
JMA	Japan Meteorological Agency
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MMD	Malaysian Meteorology Department
MNTEWC	Malaysian National Tsunami Early Warning Center
MNTEWS	Malaysian National Tsunami Early Warning System
NIED	National Research Institute for Earth Science and Disaster Resilience
PHB	Ports and Harbors Bureau
TSP	Tsunami Service Provider
PTWC	Pacific Tsunami Warning Center

INTRODUCTION

Seismicity and tectonic setting around Malaysia

Malaysia is close to the two most seismically active plate boundaries between the Indian-Australian and Eurasian plates in the west and between the Eurasian and Philippine Sea plates in the east (Figure 1). Generally, Malaysia is not seismically active unlike the neighboring countries such as Indonesia and the Philippines. However, Malaysia also has experienced local earthquakes and tremors originated from active seismic areas along subduction zones in Sumatra, Sulawesi and the Philippines.

In considering the frequency and magnitudes of earthquakes in Malaysia, as no significant tectonic earthquakes originated in the Malay Peninsula have been known before the 2007 Bukit Tinggi earthquakes, it is believed that, in the Malay Peninsula, these earthquakes are isolated and infrequent. Sarawak has experienced earthquakes of mainly local origin. Since 1874 up to now, a total of 21 earthquakes with magnitude ranging from 3.5 to 5.3 were recorded, with the Maximum Mercalli Intensity (MMI) scale of VI (ASM, 2009). Sabah received the impact of the earthquake shaking on the scale between V to VIII. Eastern Sabah especially in the districts of Sandakan, Tawau, Kunak and Semporna has the highest impact of tremors because the area is close to the medium and strong magnitude earthquake centered on the Southern Philippines and North Sulawesi. A strongest earthquake in Malaysia with magnitude 6.0 struck the Ranau District of Sabah at 7.15 am on 5 June 2015. It was centred around 10 km beneath Mount Kinabalu near the rural town of Kundasang, Sabah. Rockfalls on Mount Kinabalu due to shaking resulted in the death of 18 climbers.

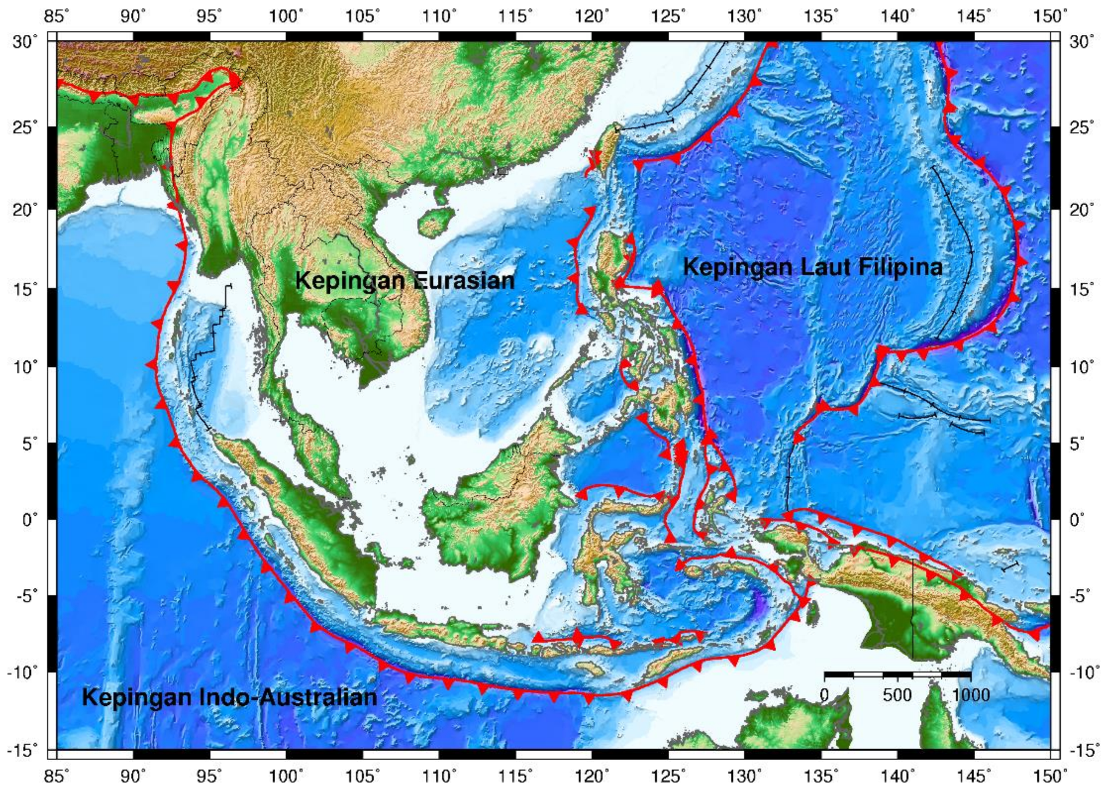


Figure 1: Plate tectonics around Malaysia (MMD)

Tsunami Risk in Malaysia

The tsunami risk areas in Malaysia are divided into two zones as shown in Figure 2. The states of Perlis, Kedah, Penang, Perak and Sabah are in high-risk zones, while other states are in low-risk zones.

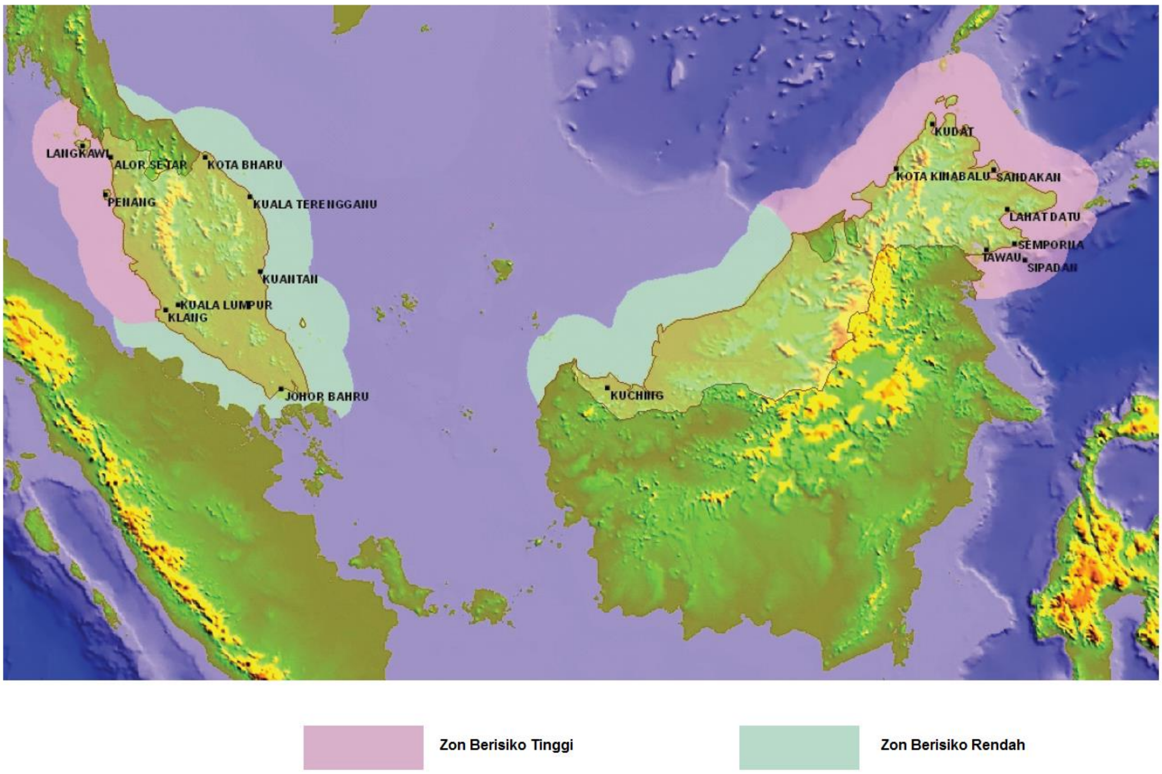


Figure 2: Tsunami Risk Zone in Malaysia (MMD & ASM, 2009)

Indian Ocean Tsunami 2004

The earthquake that occurred in the coast of North-West Sumatra with a magnitude of 9.2 on the Richter scale has caused a tsunami across the Indian Ocean. Banda Aceh in Indonesia suffered the worst impacts with deaths exceeding 200 thousand people and the destruction of property. In Malaysia, the impact of the tsunami, particularly in Kedah and Penang as shown in Figure 3, involves nearly 8,292 victims, 68 deaths, 6 missing and estimated destruction of property reaching up to RM 100 million.

Figure 3: Impact of 26 December 2004 Tsunami in Kedah and Penang

Seismicity and tectonic setting around Japan

Japan is located at the intersection of multiple oceanic plates and a continental plate, and is therefore well acquainted with the massive inter-plate earthquakes produced by plate subduction (such as the Great Kanto Earthquake of 1923, Great East Japan Earthquake 2011) as well as the inland crustal earthquakes caused by plate movements (such as the Great-Hanshin Awaji Earthquake of 1995). More than 20% of the world's largest earthquakes (magnitude 6.0 or greater) in the past decade have occurred in or around Japan. Figure 4 and 5 show map of tectonic in Japan and earthquakes causing more than 100 fatalities in Japan respectively.

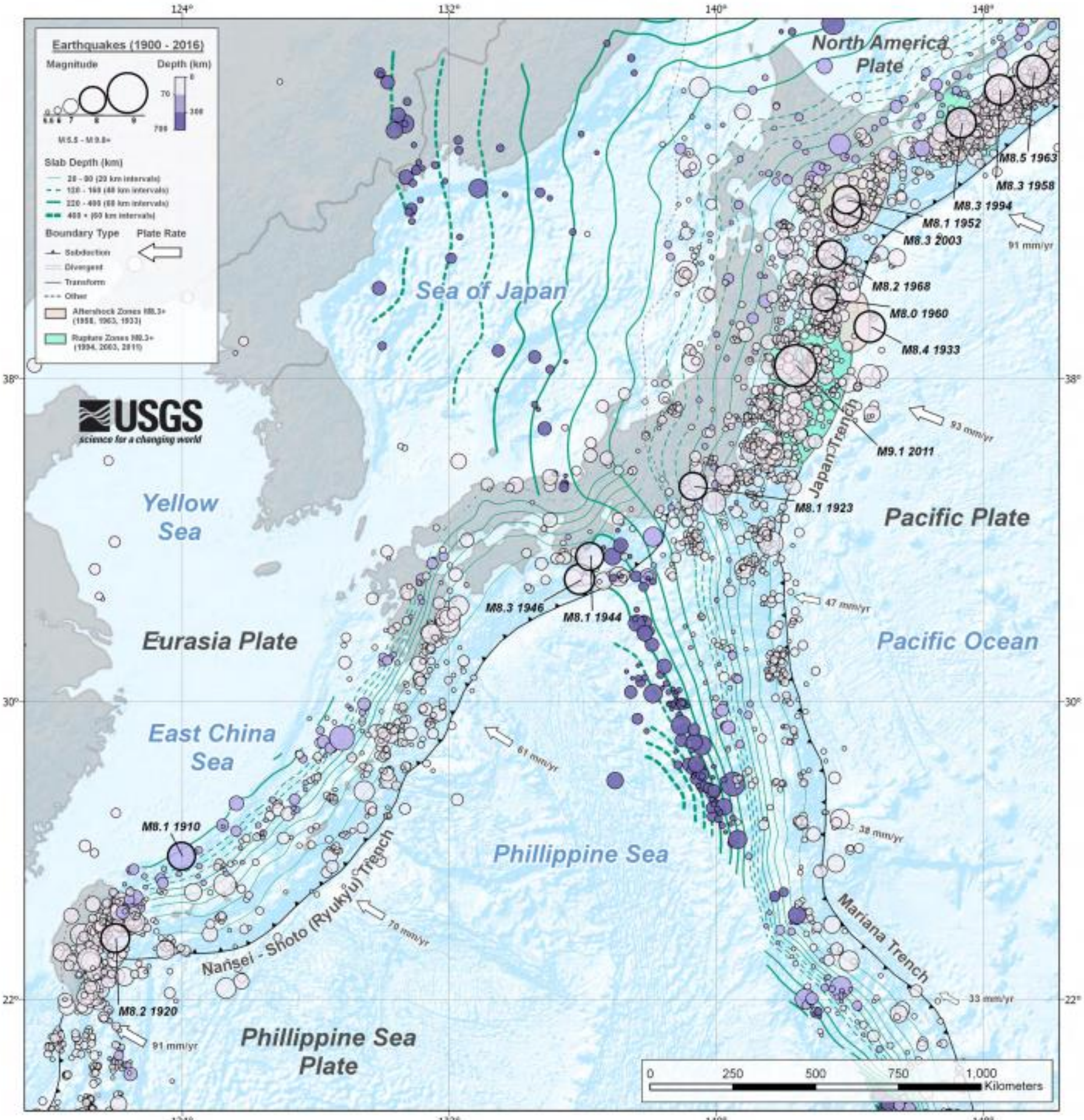


Figure 4: Map of Tectonic in Japan

Source: https://earthquake.usgs.gov/earthquakes/tectonic/images/japan_tsum.pdf

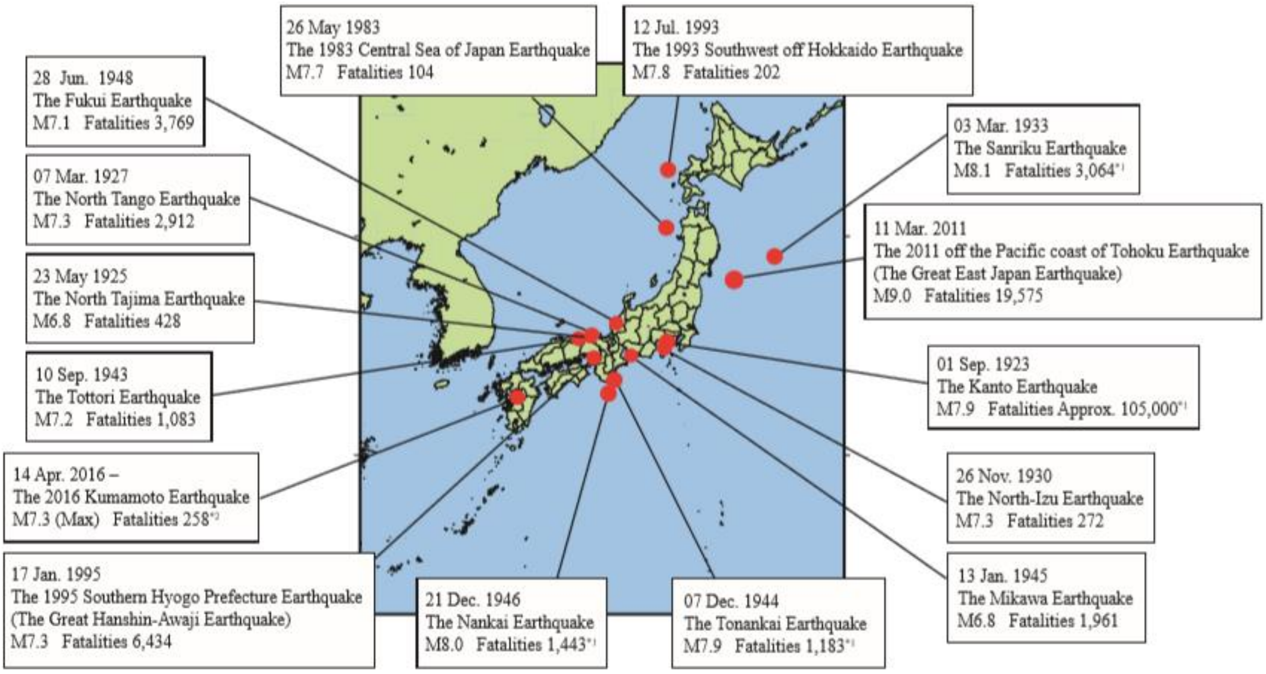


Figure 5: Earthquakes causing more than 100 fatalities (from 1900 to 2016, as of 14 February 2018)

Source: https://www.jma.go.jp/jma/kishou/books/jishintsunami/en/jishintsunami_en.pdf

Overview Malaysian National Tsunami Early Warning System (MNTEWS)

The Malaysian National Tsunami Early Warning Center (MNTEWC) is being established by end of 2005 just after the December 2004 Tsunami and located at the Malaysian Meteorological Department (MMD) in Petaling Jaya, Selangor. Presently, the MNTEWC is responsible for issuing earthquake information and tsunami advisory and warning.

The Malaysian National Tsunami Early Warning System (MNTEWS) comprises of three components, a Monitoring and Data Collection Component, a Processing and Analysis Component and a Dissemination Component. The Monitoring and Data Collection Component is made up of 17 tide gauges, 77 seismic stations and 18 coastal cameras. The Processing and Analysis Component consists of a modeling database and an integration system while the Dissemination Component consists of SMS, fax, hotline, media, webcast and 53 sirens.

The Malaysian National Tsunami Early Warning Center (MNTEWC) operates 24 hours, 7 days a week to ensure detection and dissemination of earthquake and tsunami information and warnings to the authority and public. Daily checks and scheduled maintenance of MNTEWS are carried out to ensure the system is always operational.

The areas of Responsible (AOR) under MNTEWC is within 30°N to 15°S latitude and 85°E to 140°E longitude as shown in Figure 6. Earthquakes are classified into three main categories as shown in Table 1.

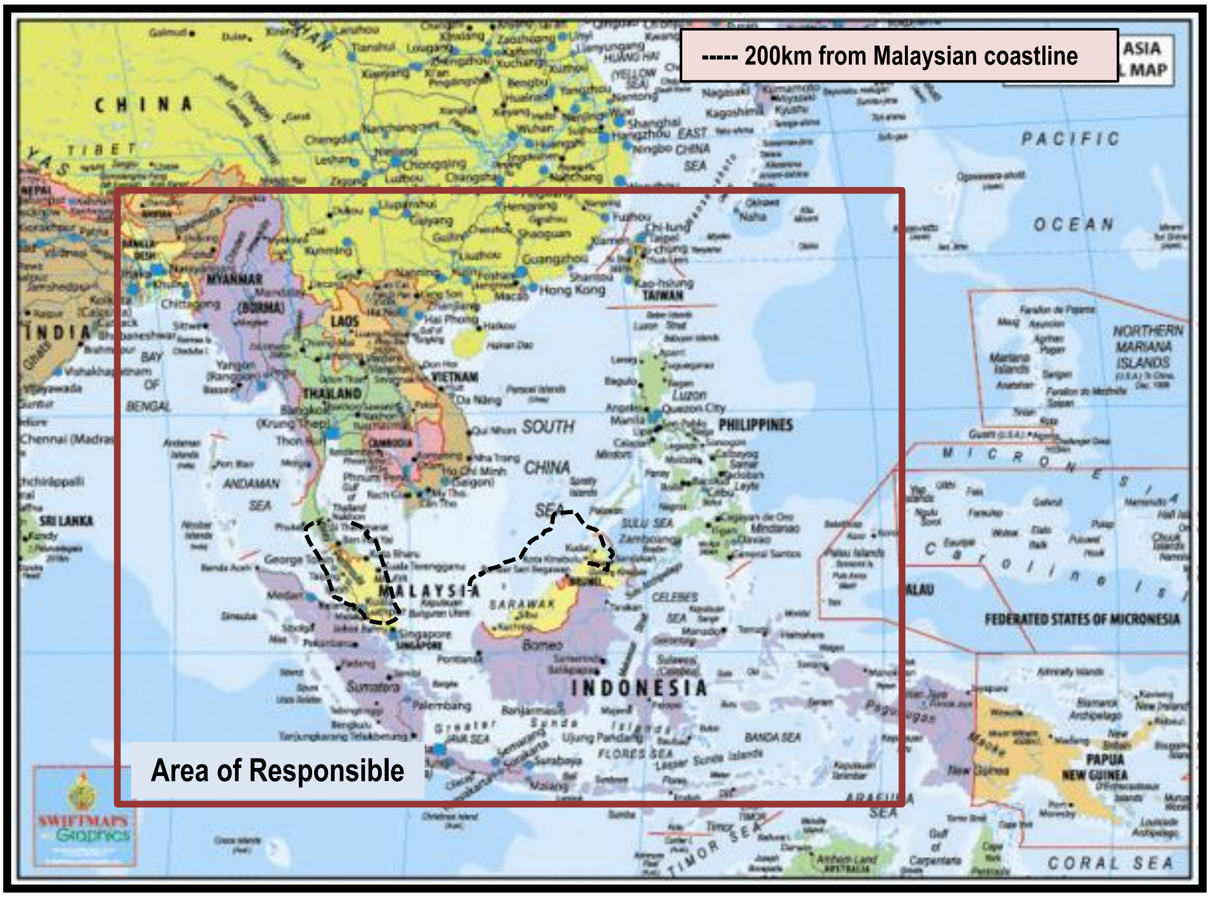


Figure 6: Area of Responsible (AOR)

Table 1: Earthquake Categories

Magnitude (Richter Scale)	Category
6.0 or more	Strong
5.0 - 5.9	Moderate
Less than 5.0	Weak

The MNTEWC will release earthquake information according to the following three conditions:

a) Within 200 km of Malaysia Coastline - Earthquakes with magnitudes 3.0 on the Richter Scale and above

b) Within the AOR area - Earthquakes with magnitudes 5.0 on the Richter Scale and above

c) Outside of AOR - Earthquakes with magnitudes 6.0 on the Richter Scale and above

Levels of Earthquake/ Tsunami Warning in Malaysia

The earthquake/tsunami emergency will be managed based on the criteria and categories defined as follows:

a. Local earthquakes of magnitude 5.5 or more on the Richter scale on land. There is possibility of damage locally.

b. Earthquakes of magnitude 6.5 and above on the Richter scale occurring in the sea and generating a tsunami that have the possibility to hit the Malaysian coastline.

Warning Criteria of Tsunami in Malaysia

In the event of tsunami threat to the Malaysian coastlines, the types of Alert to be issued:

<table>
<tr><th rowspan="2">Location</th><th></th><th colspan="2">Criteria Alert</th><th rowspan="2">Type of Alert issued</th></tr>
<tr><th>Focal Depth (km)</th><th>Magnitude (M)</th><th>Tsunami Height (meter) at Malaysian coastlines</th></tr>
<tr><td rowspan="2">South China Sea, Sulu Sea, Celebes Sea, Indian Ocean (Andaman & Nicobar), Straits of Makassar, Java Sea, Flores Sea, Banda Sea</td><td rowspan="4">$<$ 100km</td><td>$M \geq 7.5$</td><td>≥ 0.5 m</td><td>Tsunami Warning</td></tr>
<tr><td>$7.5 > M \geq 6.5$</td><td>≤ 0.5 m</td><td>Tsunami Advisory</td></tr>
<tr><td rowspan="2">Other Areas from the above</td><td rowspan="2">$M > 7.9$</td><td>≥ 0.5 m</td><td>Tsunami Warning</td></tr>
<tr><td>≤ 0.5 m</td><td>Tsunami Advisory</td></tr>
</table>

Cancellation / Termination of Tsunami Warning

Will be issued when the tsunami does not affect Malaysian coastlines or the tsunami is no longer a threat to the coasts of the country.

Type of Alert	Criteria	Message	Alert issued to
Termination/ Cancellation	Issued in the case where forecast tsunami is not generated or observed wave heights have diminished to non-destructive levels	"no longer tsunami threat"	NADMA, relevant disaster management agencies and Media

Telecommunication Systems with Global Telecommunication System (GTS), Pacific Tsunami Warning Center (PTWC), Japan Meteorological Agency (JMA) and Tsunami Service Provider (TSP) Australia, India and Indonesia

MNTEWC also available get information through GTS from PTWC in Honolulu Hawaii, JMA in Tokyo and TSP in Indonesia, India and Australia. This relationship provides a direct communication facility to receive tsunami information and warnings occur in the Pacific Ocean, the South China Sea and the Indian Ocean. Supporting information from this international contact helps MNTEWC in the verification of earthquakes and tsunami warnings.

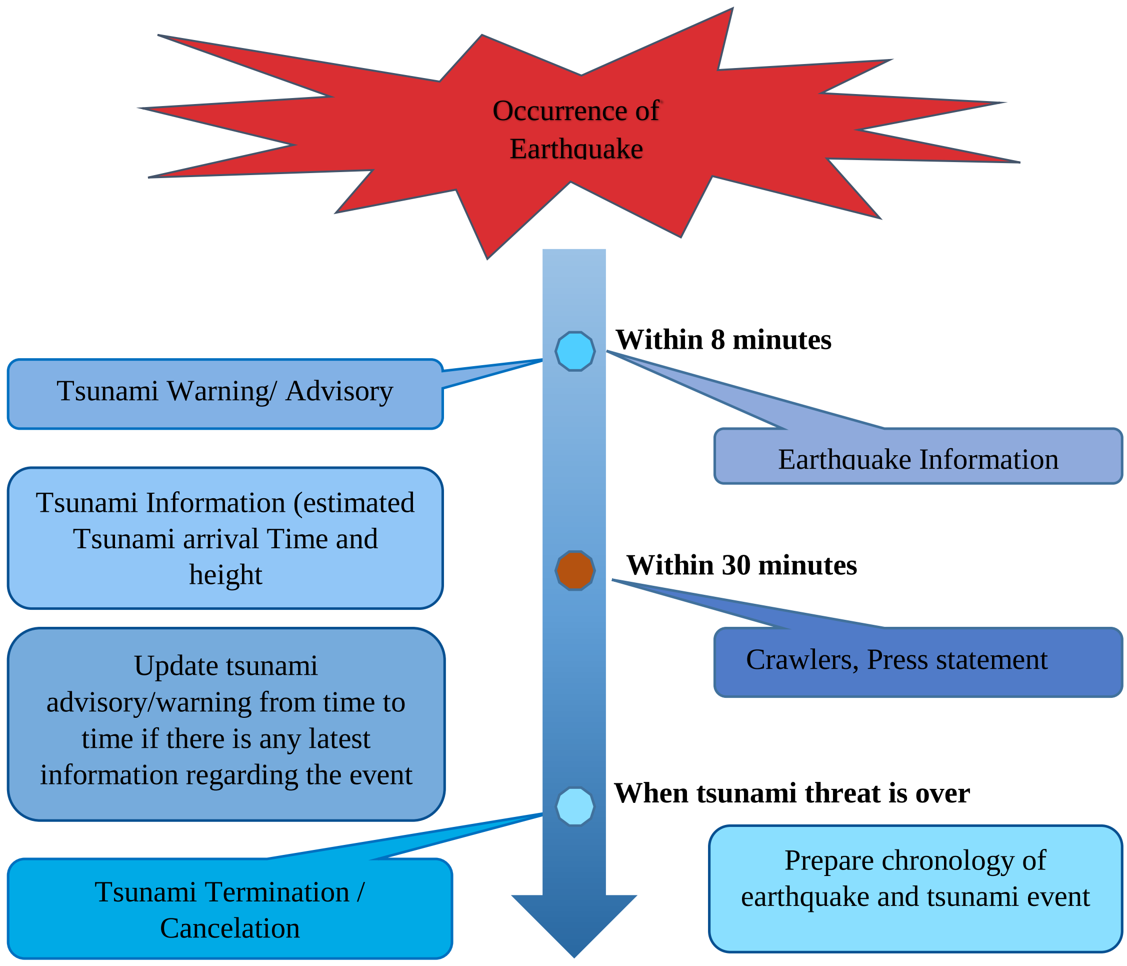


Figure 7: Flow of issuance of information about tsunami and earthquake in Malaysia

The Role of Japan Meteorology Agency in Earthquake and Tsunami Early Warning

JMA has installed seismometers at about 180 sites nationwide (approximately every 60 km). It also constantly monitors seismic activity by collecting observation data from online data sources, including high-sensitivity seismometers used by research institutions. The JMA issues seismic intensity information for a total of approximately 3,900 locations nationwide. JMA has installed about 600 seismic intensity meters nationwide (approximately every 20 km) to measure the intensity of ground motion, as well as data from seismic intensity meters installed by local governments at about 2,800 sites, and data from strong-motion seismographs installed by the National Research Institute for Earth Science and Natural Disaster Prevention (NIED) about 470 of its approximately 1,000 strong-motion seismic observation (K-NET) facilities. In addition, to gain a more thorough understanding of earthquakes and crustal activities and to provide basic observations for survey research, earthquake observations are conducted using high-sensitivity seismometers and broadband seismometers through partnerships with relevant research institutions such as the NIED, in accordance with the guidelines of the national government's Headquarters for Earthquake Research Promotion. The Geographical Survey Institute (GSI) has set up about 1,200 GPS stations all over Japan to form the GPS Earth Observation Network (GEONET), which it uses to monitor and analyze crustal movements based on regular field measurement data. These observation data are shared with relevant organizations.

As soon as an earthquake occurs in or around Japan, the JMA analyzes the data from various seismometers and seismic intensity meters. Within about two minutes, it issues a "seismic intensity information" report for earthquakes of intensity 3 or greater, and within five minutes issues an "earthquake information" report indicating the hypocenter and magnitude of the earthquake, and the seismic intensity in the municipalities where strong shaking was observed.

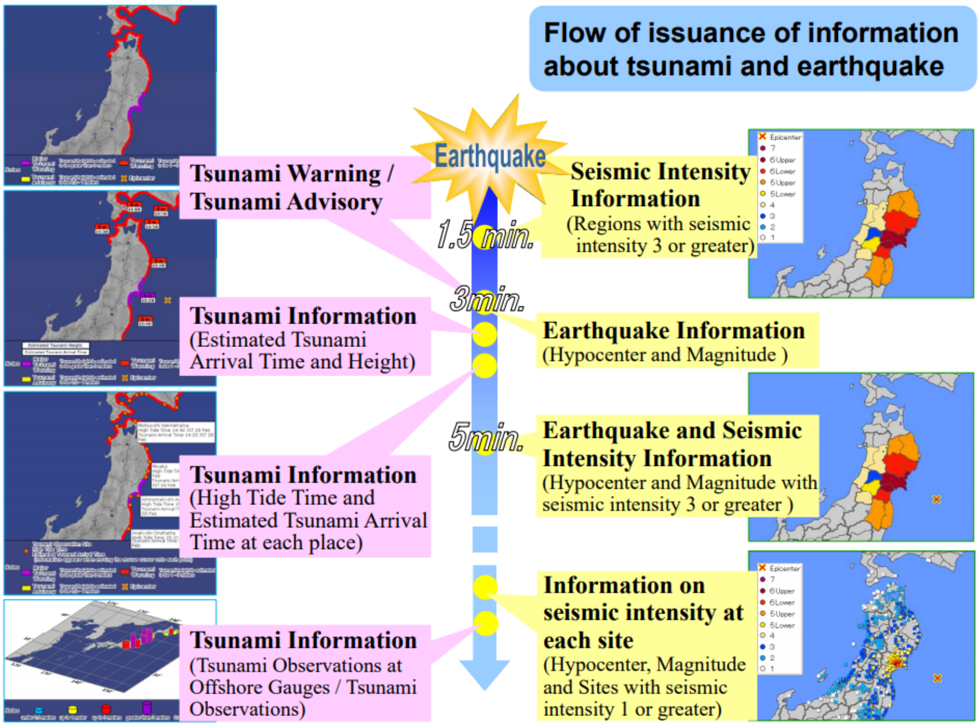


Figure 8: Flow of issuance of information about tsunami and earthquake in Japan (JMA)

Tsunami Warnings/Advisories, Tsunami Information in Japan

JMA issues Major Tsunami Warnings, Tsunami Warnings and/or Tsunami Advisories for individual regions based on estimated tsunami heights within around three minutes of the quake. It subsequently provides information on estimated wave arrival times and heights for relevant forecast regions and data on high-tide times and estimated arrival times for selected points. Immediately after an earthquake, JMA estimates its location, magnitude and the related tsunami risk. However, it takes time to determine the exact scale of earthquakes with a magnitude of 8 or more. In such cases, JMA issues an initial warning based on the predefined maximum magnitude to avoid underestimation. When such values are used, estimated maximum tsunami heights are expressed in qualitative terms such as "Huge" and "High" rather than as quantitative expressions. Once the exact magnitude is determined, JMA updates the warning with quantitatively estimated maximum tsunami heights, which are included in subsequent tsunami information.

Categories	Criteria	Estimated maximum tsunami heights in Tsunami Information		Expected damage and action to be taken
		Quantitative expression	Qualitative expression	
Major Tsunami Warning*	Tsunami height is expected to be greater than 3 meters	Over 10m (10m –)	Huge	A tsunami of this scale is expected to cause serious damage. Wooden buildings will be completely destroyed and/or washed away, and people will be caught in tsunami currents. Evacuate immediately to a safer place such as high ground or an evacuation building.
		10m (5m – 10m)		
		5m (3m – 5m)		
Tsunami Warning	Tsunami height is expected to be up to 3 meters.	3m (1m – 3m)	High	A tsunami of this scale is expected to cause damage in low-lying areas. Wooden buildings will be flooded and people will be caught in tsunami currents. Evacuate immediately to a safer place such as high ground or an evacuation building.
Tsunami Advisory	Tsunami height is expected to be up to 1 meter.	1m (0.2m – 1m)	N/A	A tsunami of this scale is expected to result in people being caught in strong currents in the sea. Fish farming facilities will be washed away and small vessels will capsize. Get out of the water and leave coastal regions immediately.

* Major Tsunami Warnings are issued in the classification of Emergency Warnings

Source: https://www.jma.go.jp/jma/kishou/books/jishintsunami/en/jishintsunami_en.pdf

OBJECTIVE

Objective of this study are:

i. To study the Earthquake and Tsunami Early Warning System in Japan Meteorology Agency (JMA)

ii. To compare Standard Operation Procedure (SOP) used by JMA and MMD in dissemination of earthquake and tsunami warning information.

iii. To improve MMD Standard Operation Procedure (SOP) in dissemination of earthquake and tsunami warning information.

METHODOLOGY

The research study is based on qualitative research methods. Information about earthquake and tsunami early warning system gather from field visits, discussions and lectures to analyze the practices and policies. I also have interviews for collecting data on individuals' personal histories, perspectives, and experiences such as meet with JMA officer. The discussions and lecture with various government officials and disaster management experts was conducted during this programme and give information about this research study. Information also gather from JMA and MMD official website.

Figure 9: Visiting Researcher visited Japan Meteorological Agency in Tokyo

Figure 10: Visiting Researcher visited the Japan Meteorological Agency Kobe Office

Figure 11: Device for reading Seismic Intensity Meter

DISCUSSION

Observation Network for Earthquake/ Tsunami Monitoring in Japan and Malaysia

Table 1.0 shows comparison between Observation Network for Earthquake/ Tsunami Monitoring in Japan and Malaysia. This is appropriate because Japan more prone to earthquake and tsunami compare to Malaysia. Population in Japan almost four times compared to Malaysia where is the total population in Malaysia is about 32.0 million (https://www.dosm.gov.my) and the total population in Japan is about 126.4 million (https://www.stat.go.jp/english/data/jinsui/tsuki/index.html). Malaysian National Tsunami Early Warning Center (MNTEWC) also set up three (3) buoys when established by end of 2005 in Andaman Sea (Rondo Island), South China Sea (Layang-layang Island) and Sulu Sea (Sipadan Island). These buoys had to be disposed of with the approval of Cabinet due to several factors, particularly the cost of maintenance and effectiveness and durability for long-term operations. This study finds that the importance of Seismic Intensity Meter for early information when an earthquake occurs and perhaps the government could consider for establishing at earthquake high-risk area.

Table 1.0: Observation Network for Earthquake/ Tsunami Monitoring in Japan and Malaysia (Source: JMA and MMD)

NETWORK	JAPAN	MALAYSIA
Seismometer	Approx. 1700 stations	77 stations
Seismic Intensity Meters	Approx. 4374 stations	Not Available
Tide Gauge	Approx. 188 stations	16 stations
GPS Buoys and Ocean Bottom Tsunami Meters	Approx. 240 stations	Not Available
Strain Meters	27 stations	Not Available

Time of Issuance Earthquake and Tsunami Warning Information in Japan and Malaysia

Malaysia should improve Time of Issuance Earthquake and Tsunami Warning Information as shown in Table 2.0 there are about three (3) to five (5) minute late compare to Japan. Figure 12 and 13 show example of Shake Map issued by MMD and example of Seismic Intensity Map issued by JMA.

Japan also has Earthquake Early Warning (EEW) system which is capable of issuing earthquake warning/forecast within several to over ten seconds. Warnings are disseminated widely through various media such as TV and cellular phones to help people protect themselves from strong shaking. Forecasts are issued with lower criteria and used for countermeasures against shaking, such as automatic equipment control in which trains are slowed down and factory lines are controlled before shaking starts.

Table 2.0: Time of Issuance Earthquake and Tsunami Warning Information in Japan and Malaysia (Source: JMA and MMD)

INFORMATION	JAPAN	MALAYSIA
Seismic Intensity / Shake Map	1.5 to 2 minutes	Within 8 minutes **after earthquake detected**
Earthquake	Within 5 minutes	Within 8 minutes **after earthquake detected**
Tsunami Warning	2 to 3 minutes	Within 8 minutes **after earthquake detected**
Earthquake Early Warning	Several to over ten seconds	Not Available

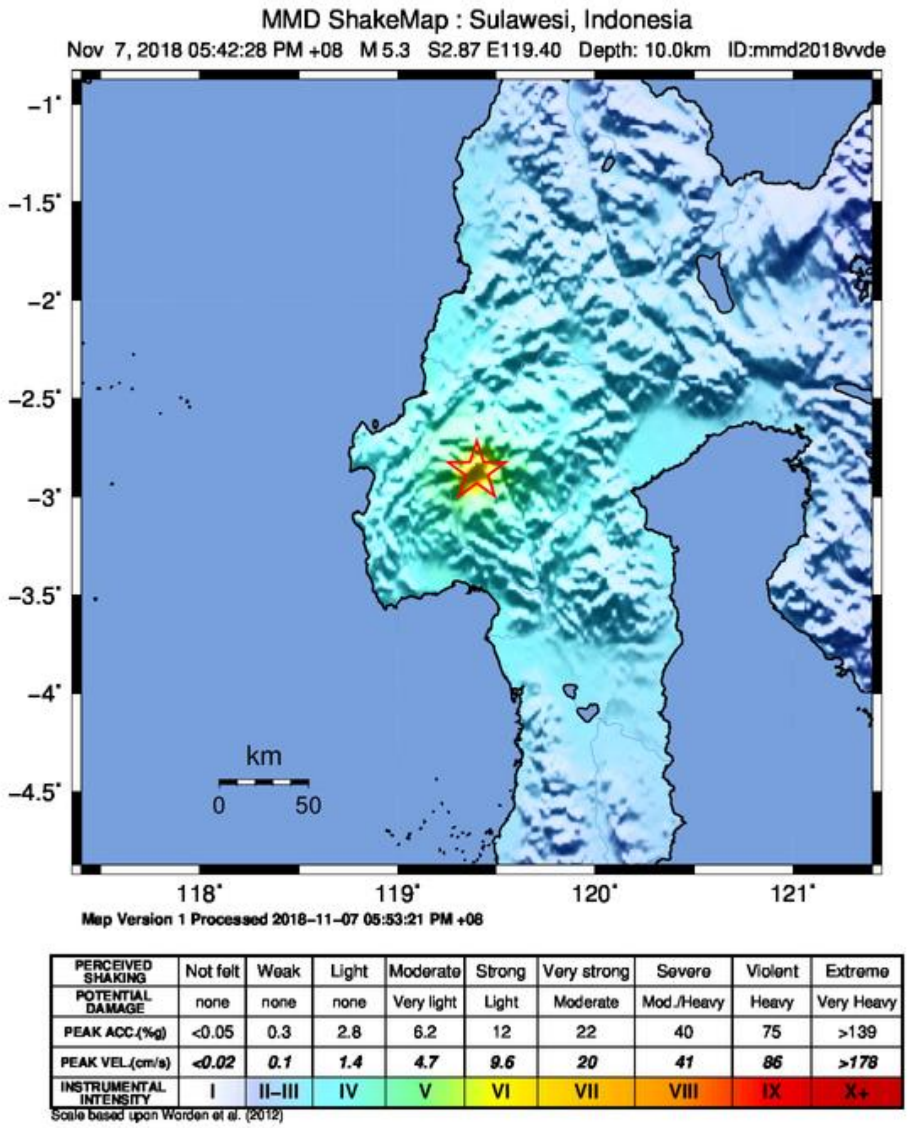
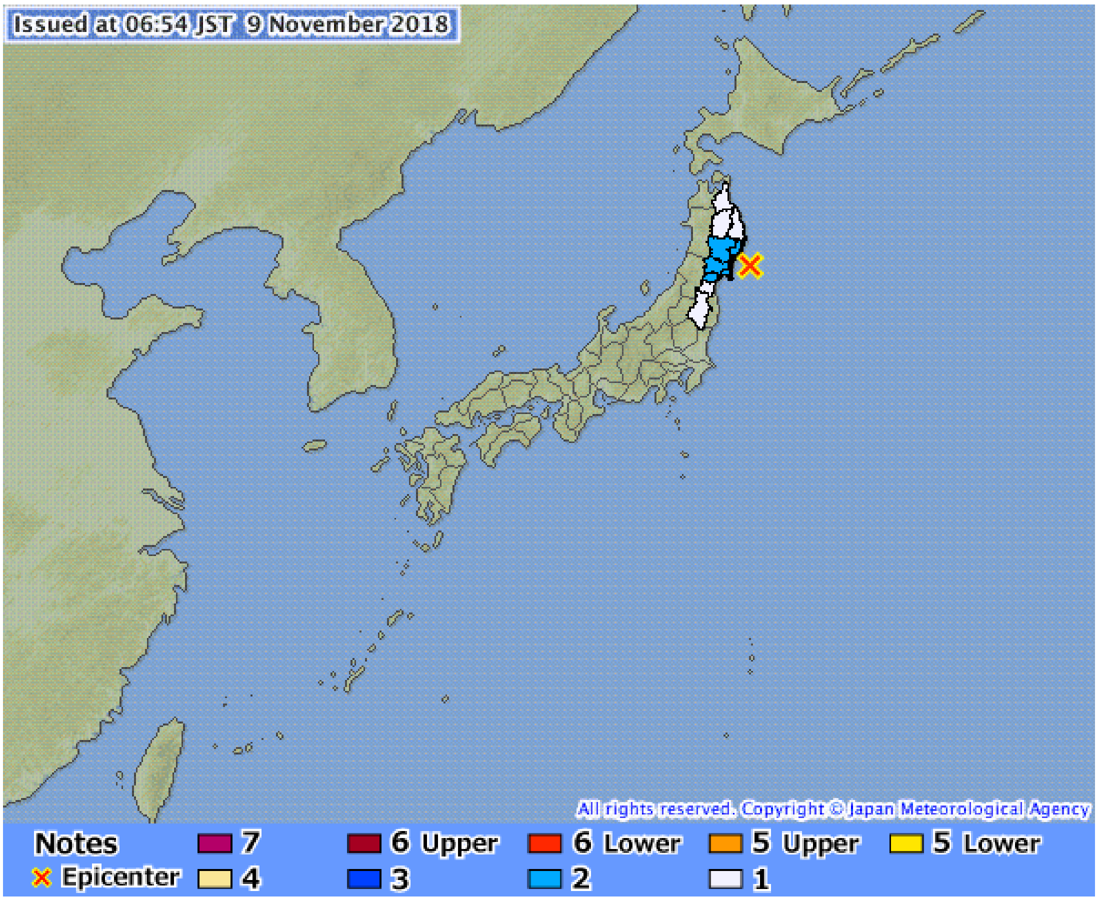


Figure 12: Example of Shake Map issued by MMD



Earthquake Information (Earthquake and Seismic Intensity Information)
Issued at 06:54 JST 09 Nov 2018

Occurred at (JST)	Latitude (degree)	Longitude (degree)	Depth	Magnitude	Region Name
06:51 JST 09 Nov 2018					

Figure 13: Example of Seismic Intensity Map issued by JMA

Categories of Tsunami Warning in Japan and Malaysia

Japan have decided four (4) categories of Tsunami Warning and Malaysia only three (3) categories as shown in Figure 14. The differences are Japan have "Major Tsunami Warning". This category was introduced on 30 August 2013 (JMA) after lesson learned from the major tsunami caused by the 2011 Great East Japan Earthquake. When "Major Tsunami Warning" was issued, immediate action should be taken to protect life. In Malaysia, MNTEWC never have experiences issues Tsunami Warning.

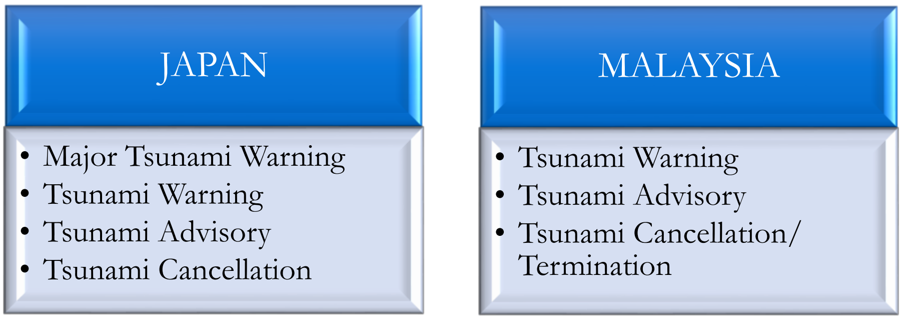


Figure 14: Categories of Tsunami Warning in Japan and Malaysia

Dissemination of Earthquake and Tsunami Warning Information in Japan and Malaysia

In Japan, the earthquake and tsunami warning information issued by the JMA will be automatically transmitted to the public via prefectures, municipalities, relevant organizations and media as shown in Figure 15. Municipalities also take responsible for issues evacuation advisory or warning. A little bit contrast to Malaysia, earthquake and tsunami warning information issued by the MMD to public not through municipalities as shown in Figure 16. Figure 17 show siren tsunami operated by MMD for tsunami warning dissemination.

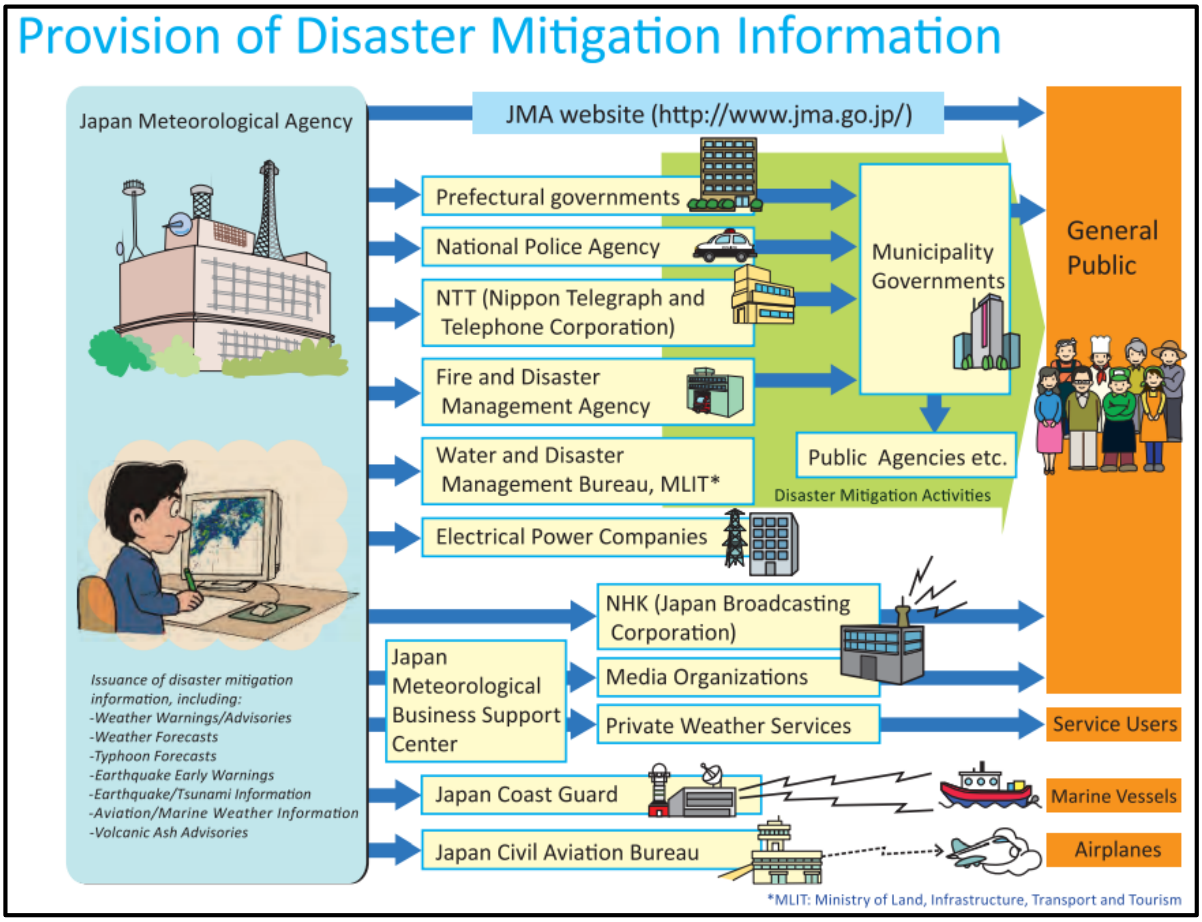


Figure 15: Dissemination of Disaster Mitigation Information in Japan

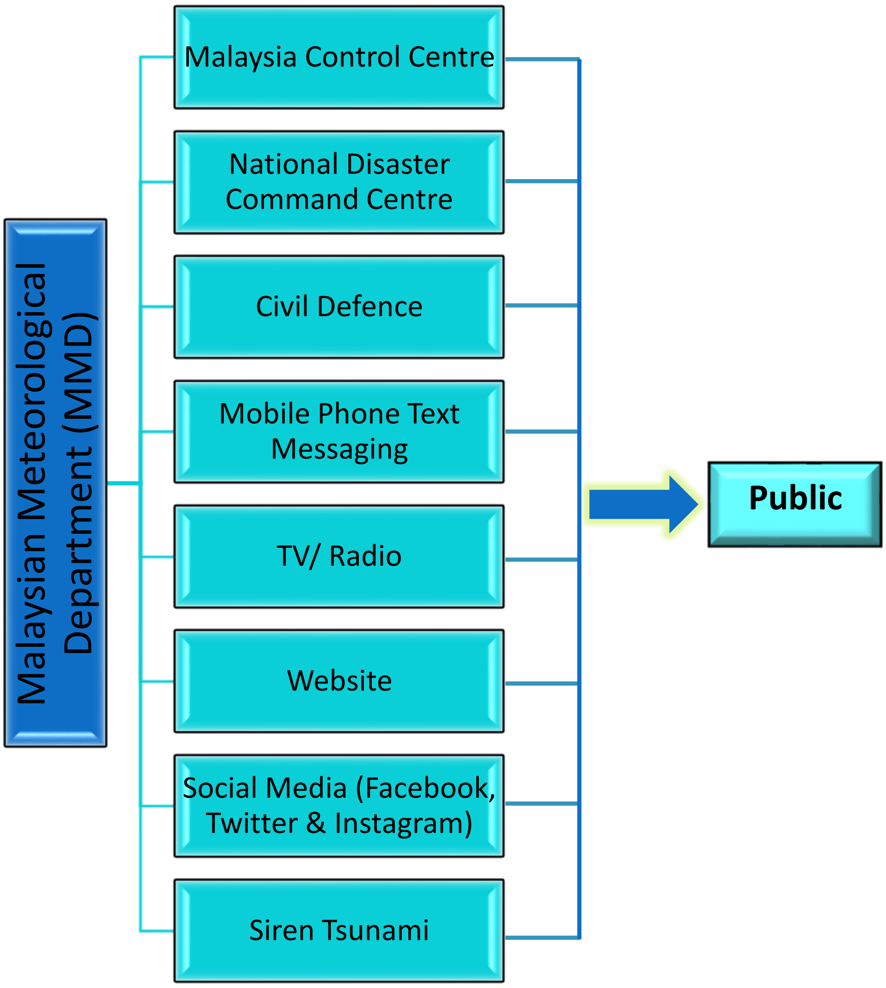


Figure 16: Dissemination of Earthquake and Tsunami Warning Information in Malaysia

Figure 17: Siren Tsunami Operated by MMD for Tsunami Warning Dissemination

CONCLUSION

Japan is country prone to earthquake and tsunami threats, therefore Japan has established Early Warning System by using the latest technology and proven can reducing the risk of disaster. In Malaysia, the tsunami warning system installed nationwide is sufficient to give early warning on tsunami. MMD need to improved time for issuance earthquake information.

Because tsunami not that common disaster in Malaysia, tsunami early warning system can be combined with other type hazards to give information to many people such as the tsunami siren is also used to inform for high tide, lightning, heavy rain, flood and so forth.

Cooperation of local or state authorities is important in enhancing understanding of the early warning system. They should be organizing public awareness activities on disasters more often in collaboration with MMD and other agencies, NGO and etc.

The effort to manage disaster risks is not meant to deal with the catastrophic situation alone but it involves efforts to increase the resilience of the community to deal with it. In this context, the co-operation of all parties is crucial to minimize the risk. An effective early warning system capable reduce death and destruction of property. Therefore, education on disaster management is one of the important aspects that must be applied to all Malaysians.

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https://www.data.jma.go.jp/svd/eqev/data/monitor/index.html

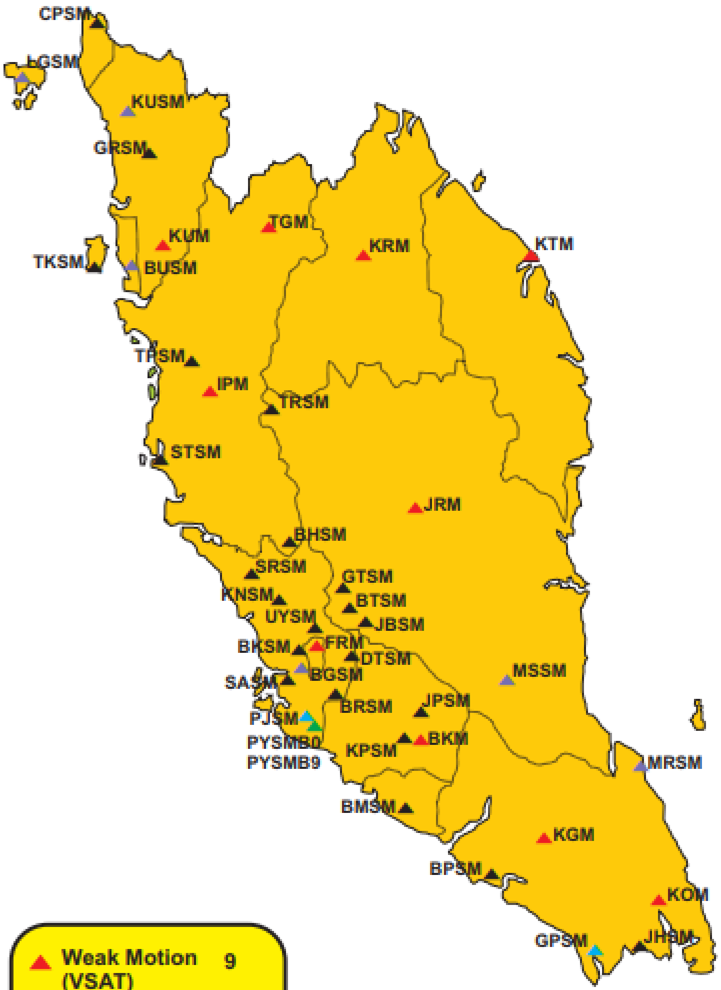
APPENDIX

Malaysian Meteorological Department
Ministry of Energy, Science, Technology, Environment & Climate Change (MESTECC)

Seismological Station -Peninsular Malaysia

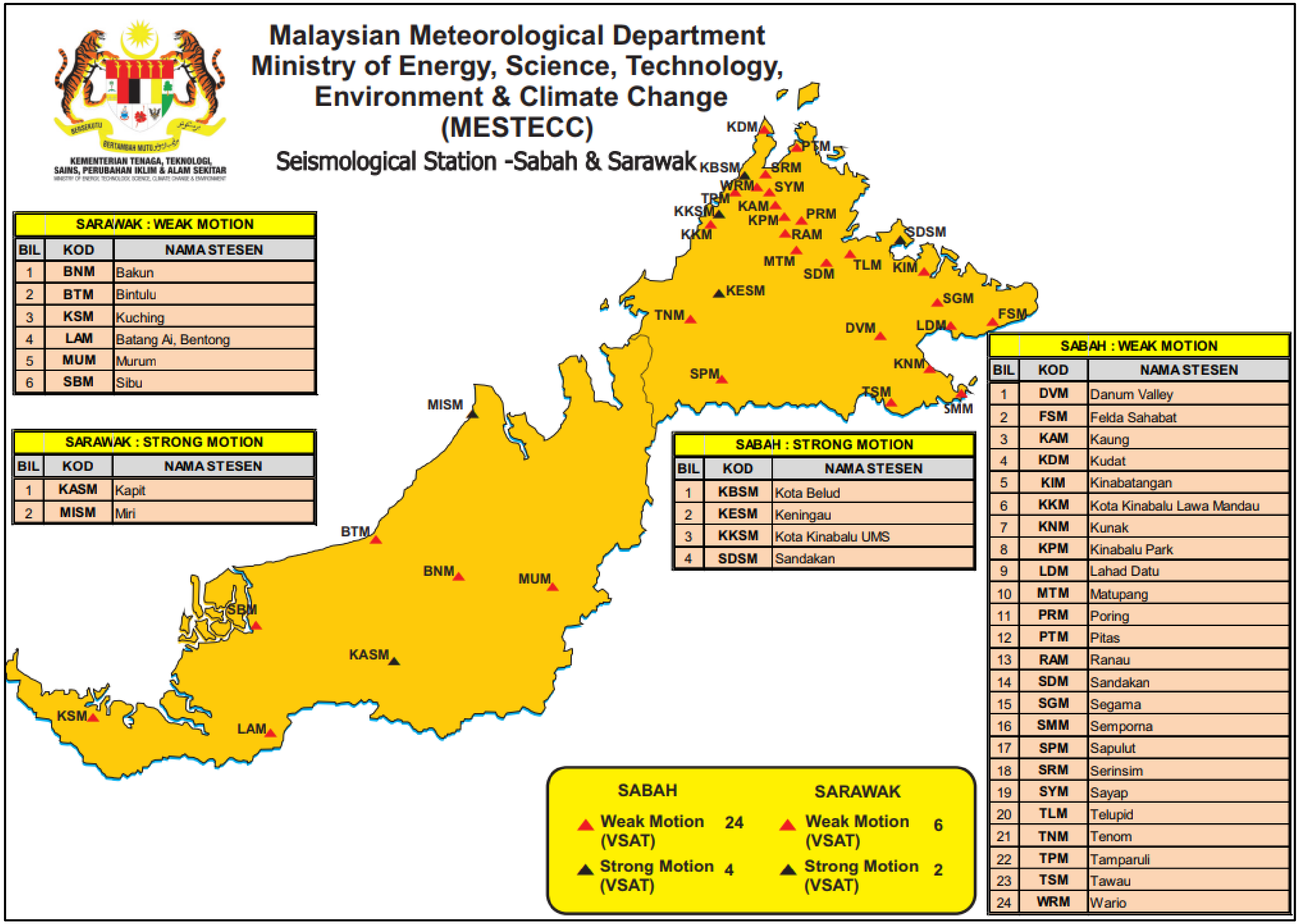
PENINSULA : WEAK MOTION		
BIL	KOD	NAMA STESEN
1	BKM	Batu Kikir Kuala Pilah
2	FRM	FRIM
3	IPM	Ipoh
4	JRM	Jerantut
5	KGM	Kluang
6	KOM	Kota Tinggi
7	KRM	Kuala Krai
8	KTM	Kuala Terengganu
9	KUM	Kulim
10	TGM	Temenggor

PENINSULA : STRONG MOTION		
BIL	KOD	NAMA STESEN
1	BHSM	Behrang
2	BGSM	Bukit Gasing,Petaling Jaya
3	BKSM	Pusat Sains Bukit Kiara
4	BMSM	Bukit Katil
5	BPSM	Batu Pahat
6	BRSM	Kolej Mara Beranang
7	BTSM	Bukit Tinggi
8	BUSM	Bukit Mertajam
9	CPSM	Chuping
10	DTSM	KBN Dusun Tua
11	GPSM	Gelang Patah
12	GRSM	Gurun
13	GTSM	Aminudin Baki Gohtong Jaya
14	JBSM	Balai Polis Janda Baik
15	JHSM	Johor Bahru
16	JPSM	Jempol
17	KNSM	Mardi Kundang Selangor
18	KPSM	Kuala Pilah
19	KUSM	Kuala Nerang
20	LGSM	Pulau Langkawi
21	MRSM	Mersing
22	MSSM	Muadzam Shah
23	PJSM	Wetland Putrajaya
24	PYSMB0	Perbadanan Putrajaya
25	PYSMB9	Perbadanan Putrajaya
26	SASM	Bukit Cerakah Shah Alam
27	SRSM	Pusat Serenti Serendah
28	STSM	Setiawan
29	TKSM	Teluk Kumbar
30	TPSM	Taiping
31	TRSM	Tanah Rata Cameron Highlands
32	UYSM	Empangan Ulu Yam



- ▲ Weak Motion (VSAT) 9
- ▲ Weak Motion (Leased Line) 1
- ▲ Strong Motion (Streamyx) 22
- ▲ Strong Motion (Maxis) 2
- ▲ Strong Motion (Leased Line) 2
- ▲ Strong Motion (VSAT) 6

Source: Malaysian Meteorological Department (MMD)



SARAWAK : WEAK MOTION

BIL	KOD	NAMA STESEN
1	BNM	Bakun
2	BTM	Bintulu
3	KSM	Kuching
4	LAM	Batang Ai, Bentong
5	MUM	Murum
6	SBM	Sibu

SARAWAK : STRONG MOTION

BIL	KOD	NAMA STESEN
1	KASM	Kapit
2	MISM	Miri

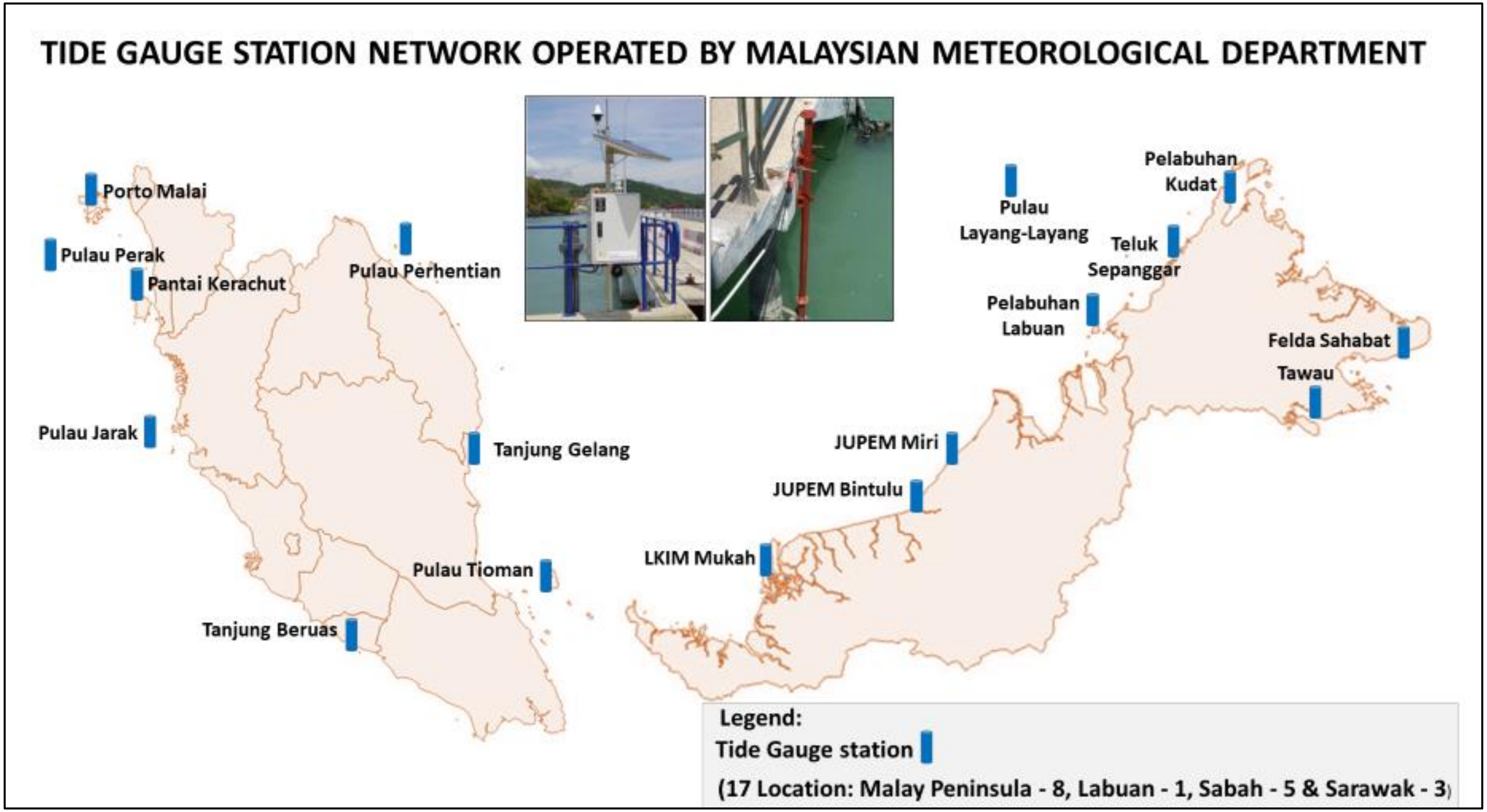
SABAH : STRONG MOTION

BIL	KOD	NAMA STESEN
1	KBSM	Kota Belud
2	KESM	Keningau
3	KKSM	Kota Kinabalu UMS
4	SDSM	Sandakan

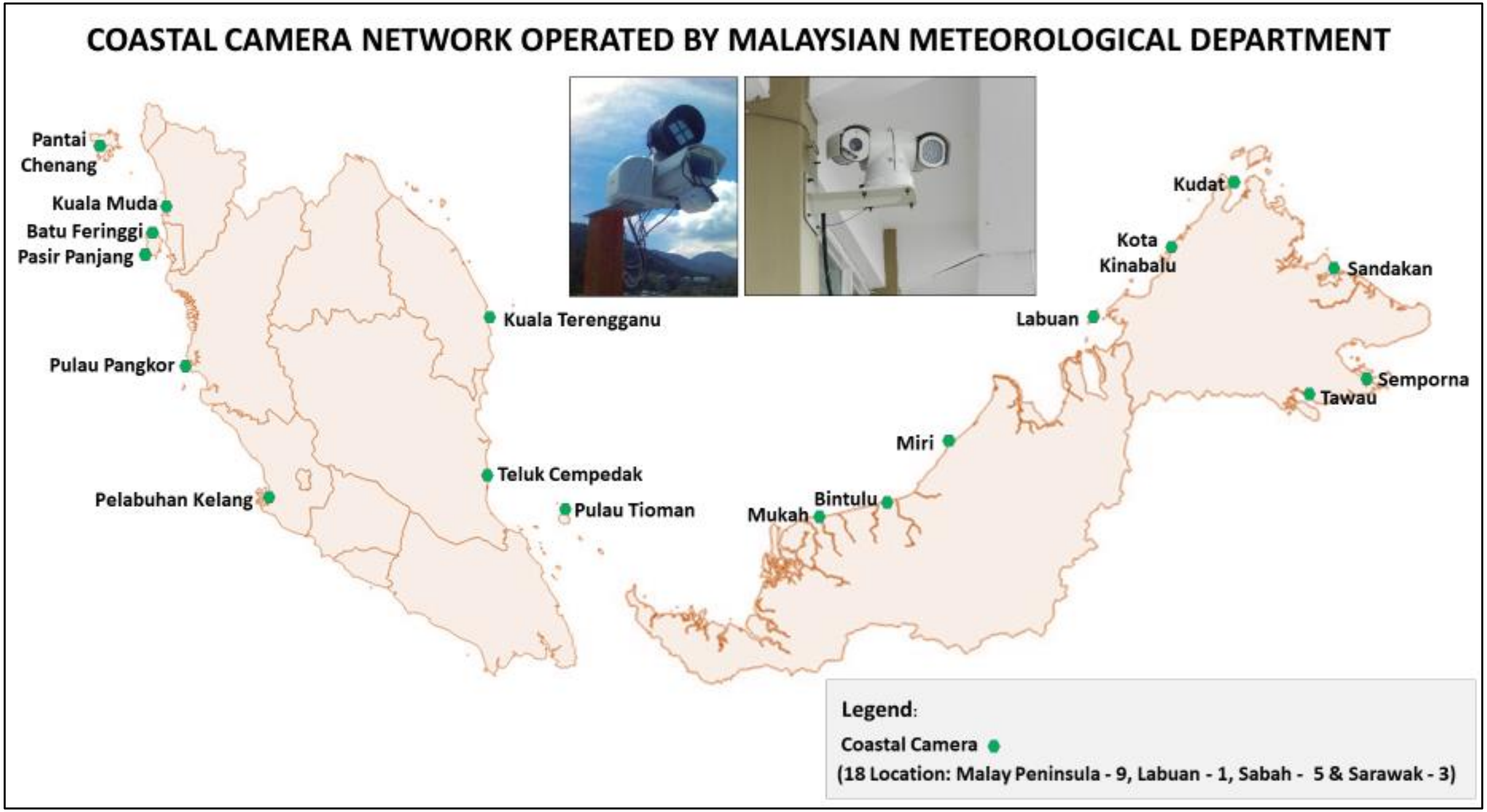
SABAH : WEAK MOTION

BIL	KOD	NAMA STESEN
1	DVM	Danum Valley
2	FSM	Felda Sahabat
3	KAM	Kaung
4	KDM	Kudat
5	KIM	Kinabatangan
6	KKM	Kota Kinabalu Lawa Mandau
7	KNM	Kunak
8	KPM	Kinabalu Park
9	LDM	Lahad Datu
10	MTM	Matupang
11	PRM	Poring
12	PTM	Pitas
13	RAM	Ranau
14	SDM	Sandakan
15	SGM	Segama
16	SMM	Semporna
17	SPM	Sapulut
18	SRM	Serinsim
19	SYM	Sayap
20	TLM	Telupid
21	TNM	Tenom
22	TPM	Tamparuli
23	TSM	Tawau
24	WRM	Wario

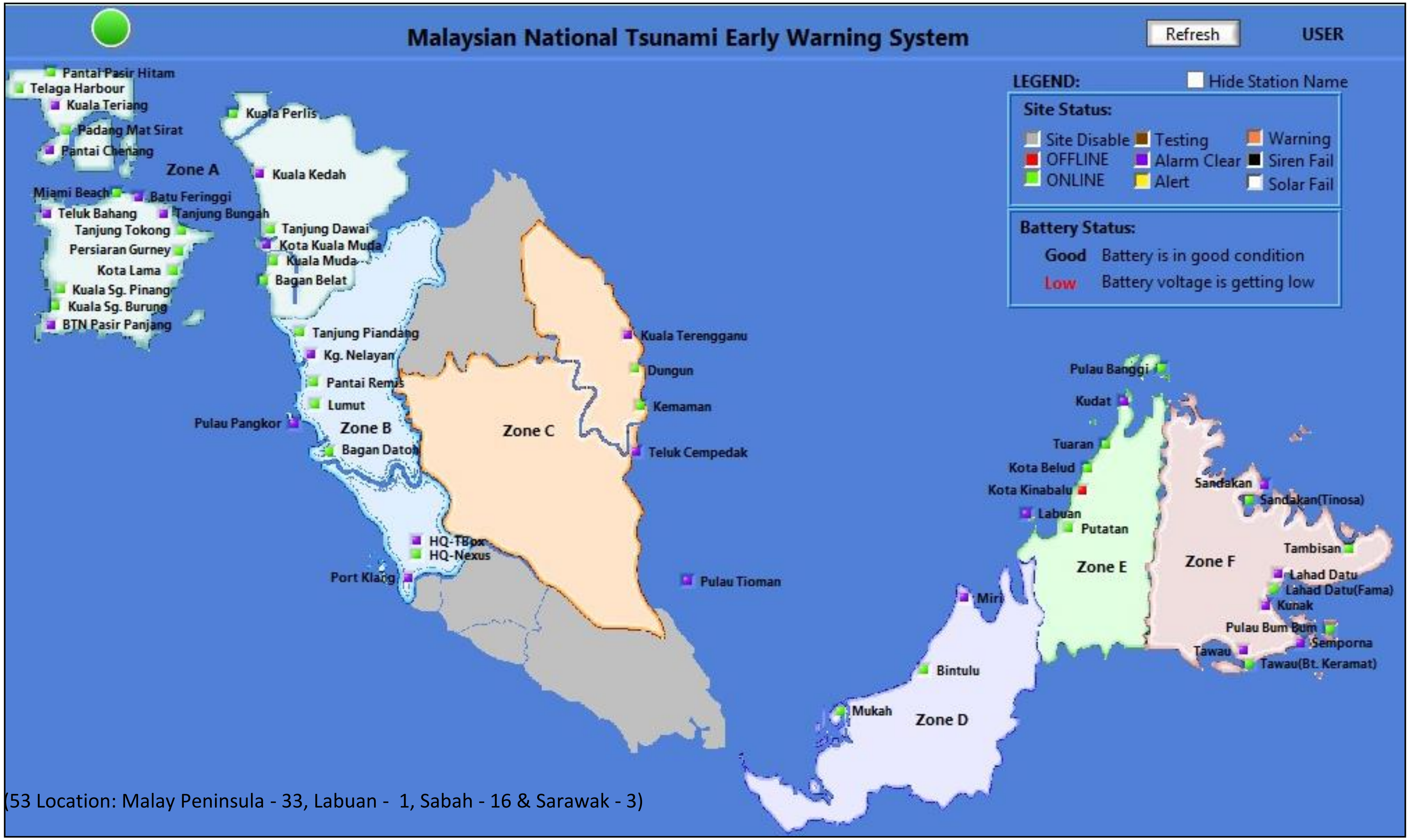
Source: Malaysian Meteorological Department (MMD)



Source: Malaysian Meteorological Department (MMD)

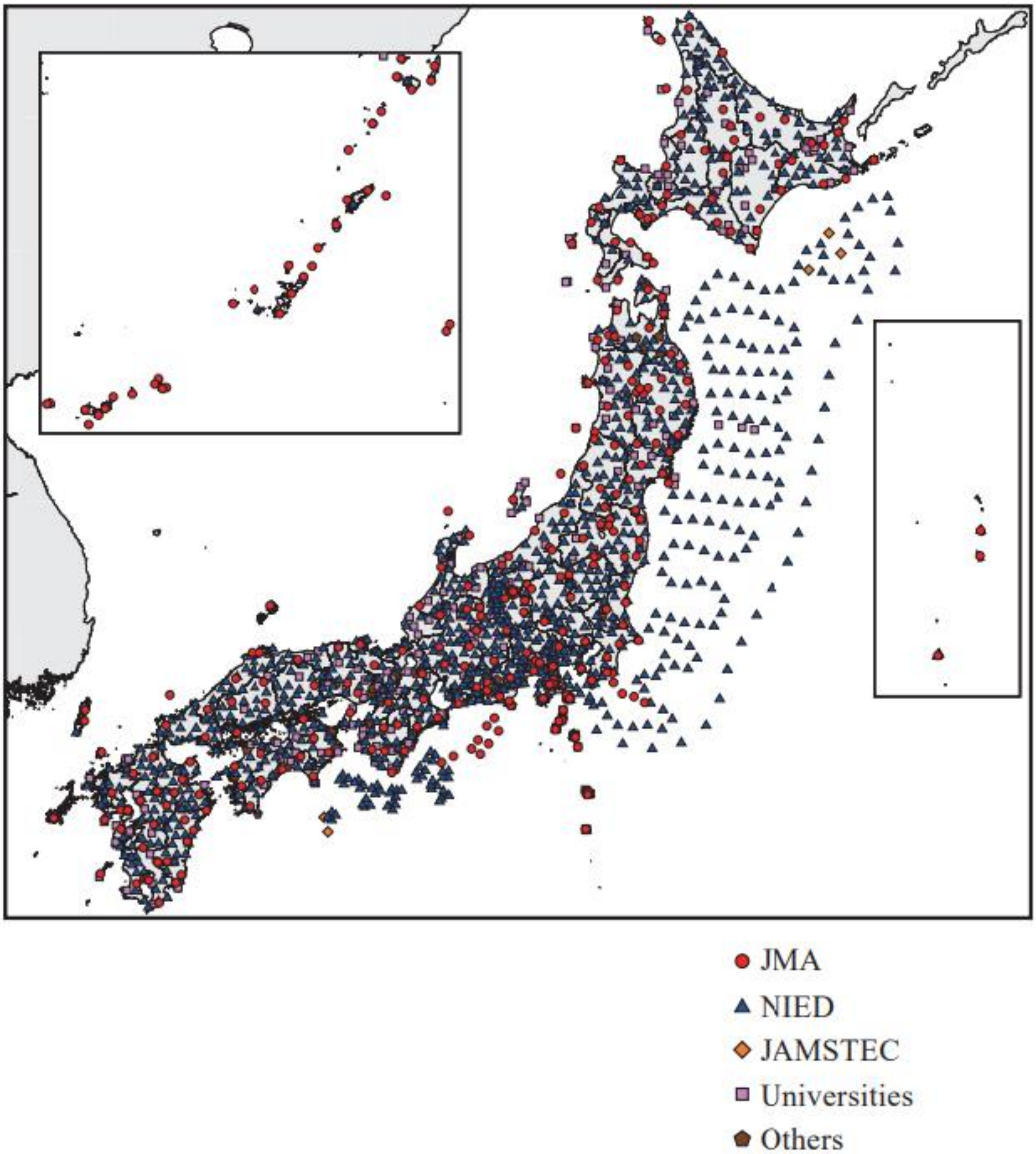


Source: Malaysian Meteorological Department (MMD)



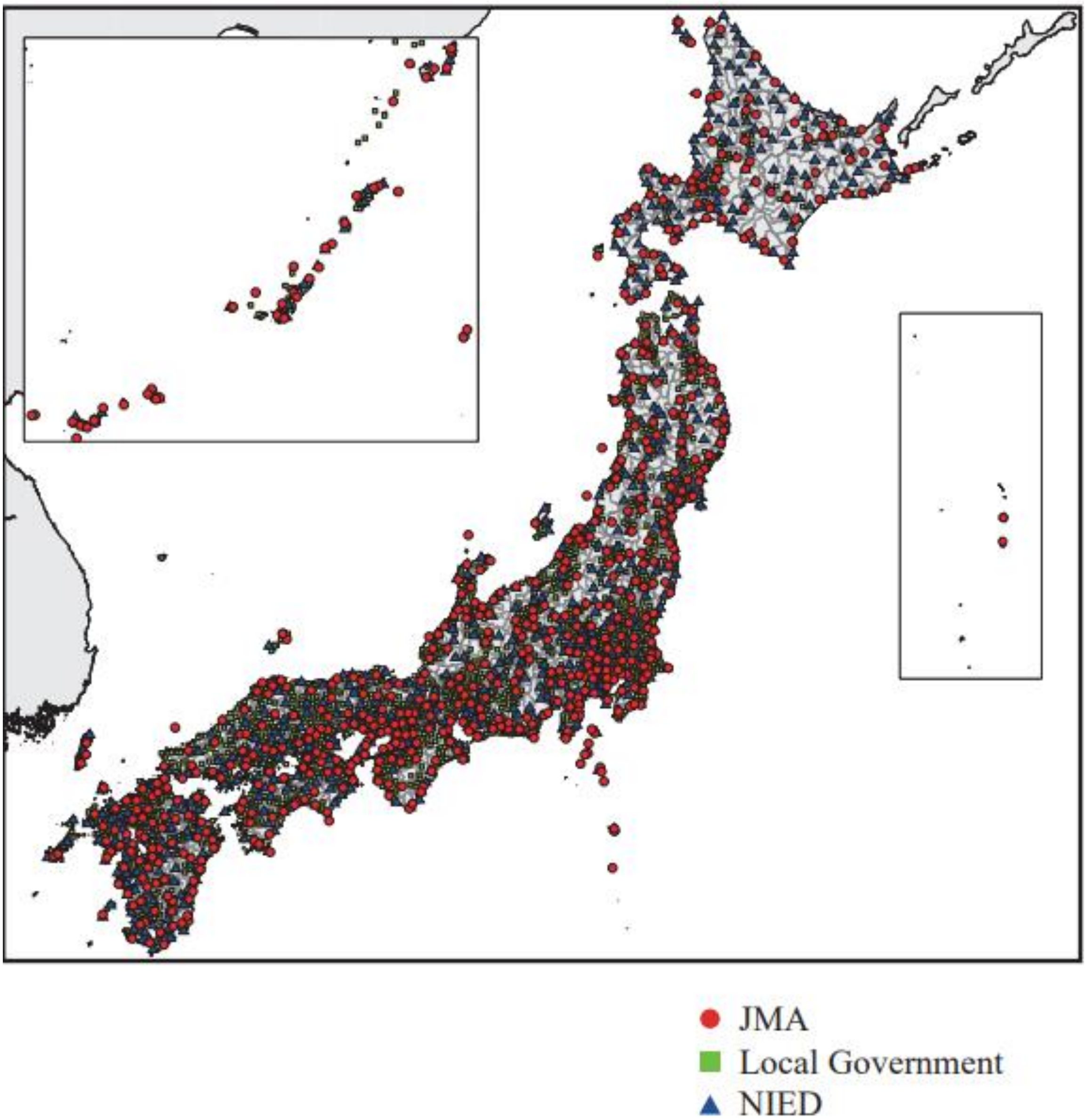
Location of Siren Tsunami in Malaysia

Source: Malaysian Meteorological Department (MMD)



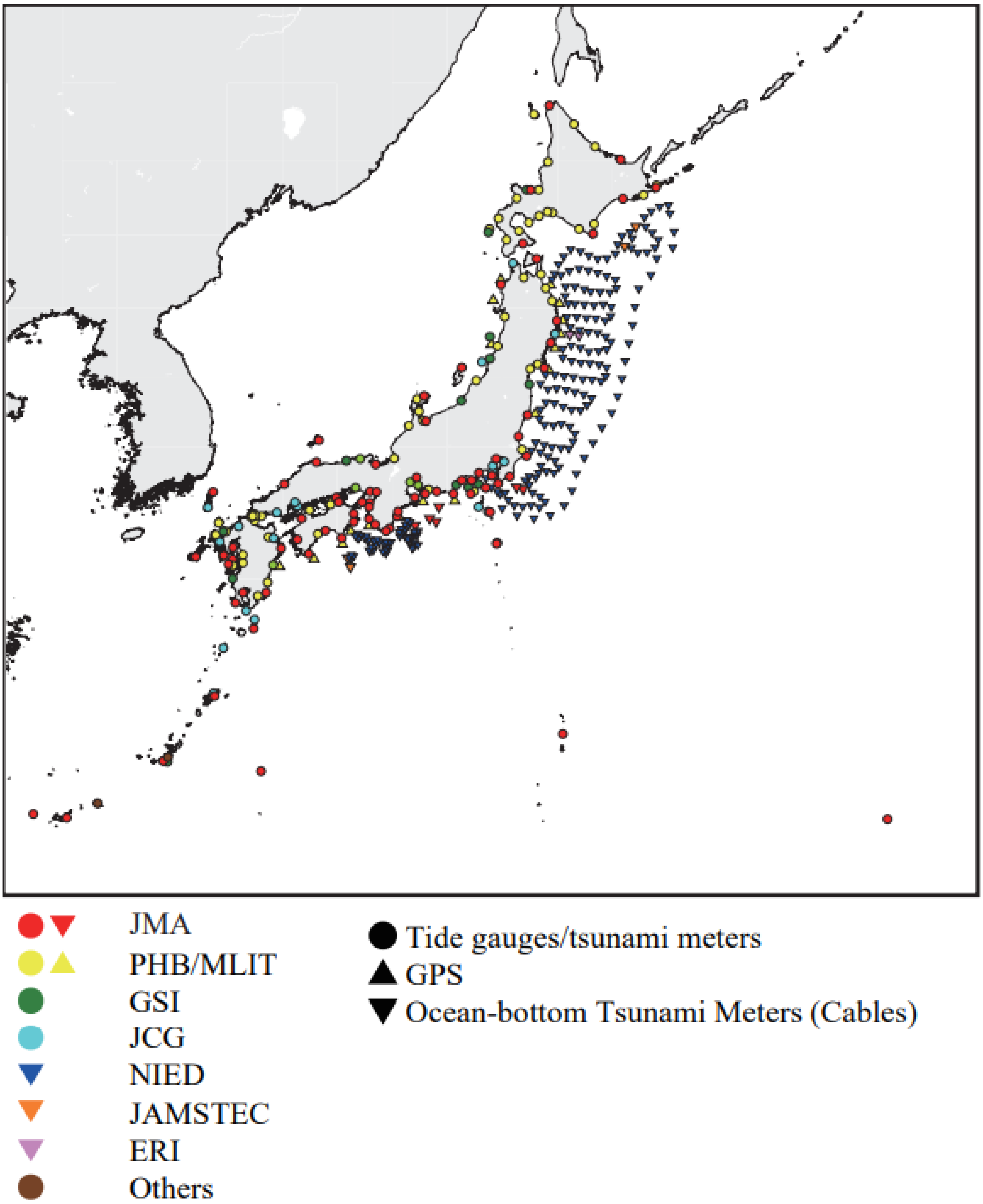
Seismometer network (as of 1 Jan. 2018)

Source: https://www.jma.go.jp/jma/kishou/books/jishintsunami/en/jishintsunami_en.pdf



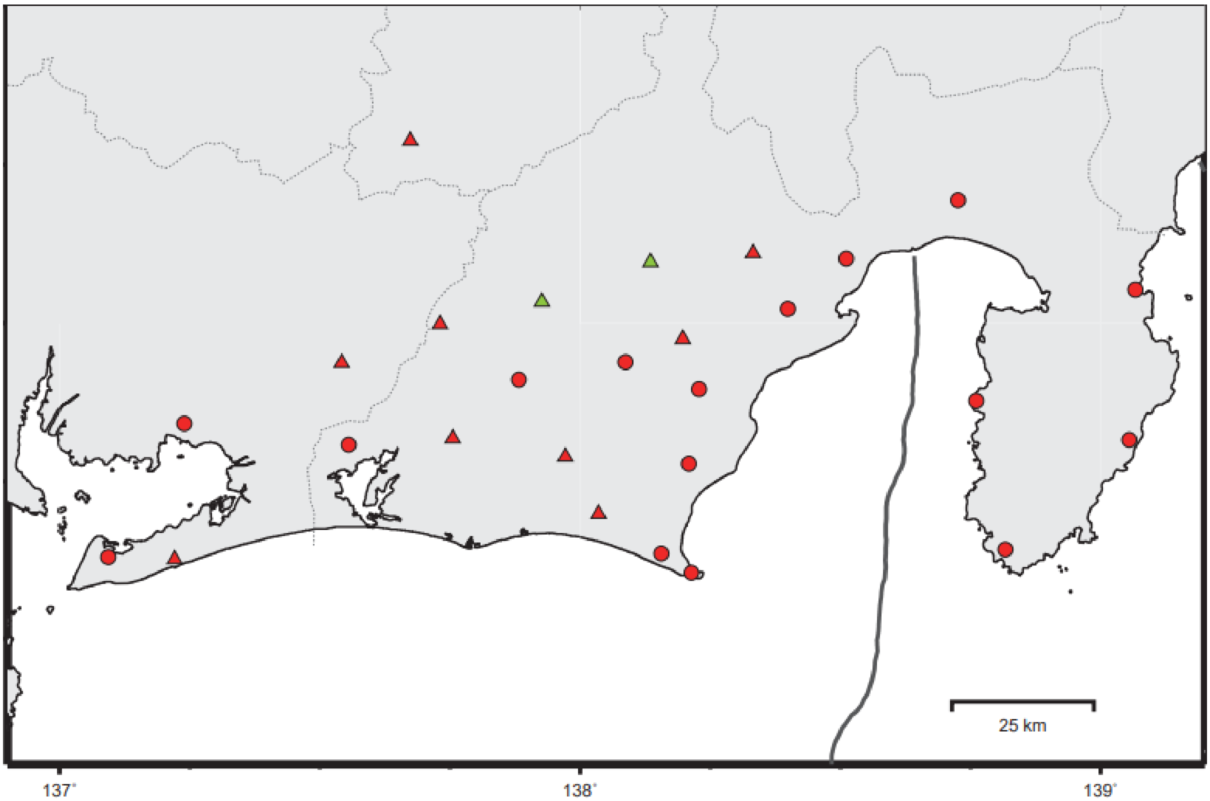
Seismic intensity meter network (as of 1 Jan. 2018)

Source: https://www.jma.go.jp/jma/kishou/books/jishintsunami/en/jishintsunami_en.pdf



Tsunami monitoring network (as of 1 Jan. 2018)

Source: https://www.jma.go.jp/jma/kishou/books/jishintsunami/en/jishintsunami_en.pdf



Strainmeter network for issuing
Nankai Trough Earthquake Information
(as of 1 Jan. 2018)

● : Borehole volume strainmeters (JMA)
▲ : Borehole multi-component strainmeters (JMA)
▲ : Borehole multi-component strainmeters (Shizuoka pref.)

Source: https://www.jma.go.jp/jma/kishou/books/jishintsunami/en/jishintsunami_en.pdf