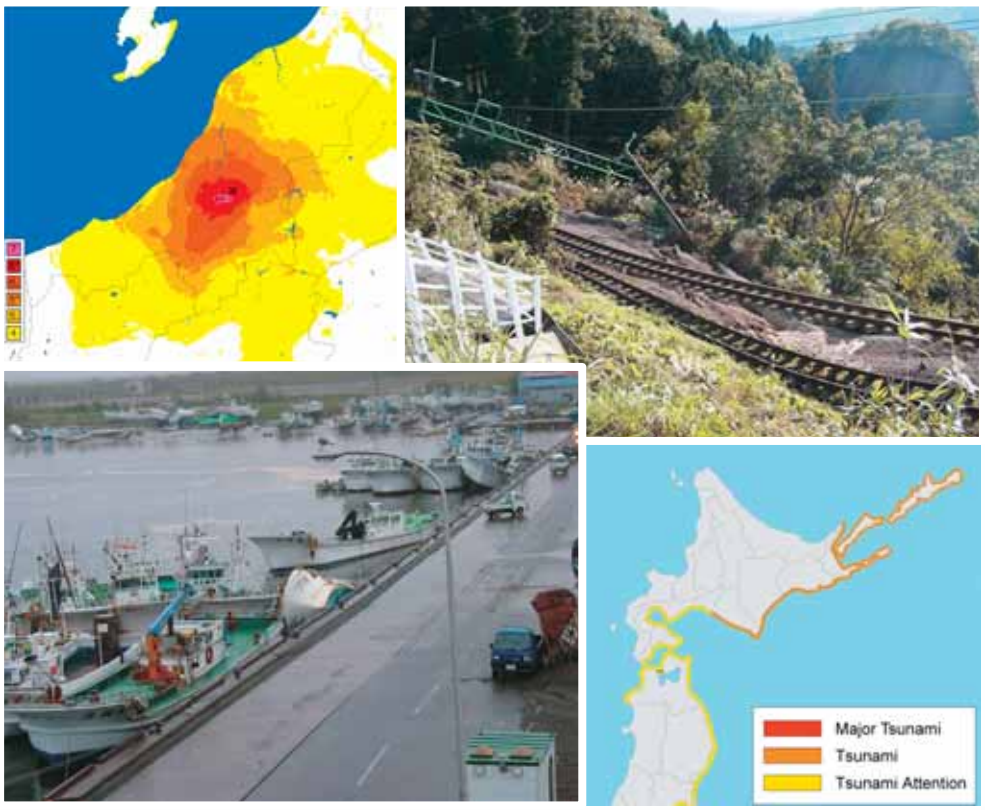
Earthquake and Tsunami

Monitoring and Information



Japan Meteorological Agency

Contents

Information on Earthquake and Tsunami

Seismic Activities and Information on Earthquake & Tsunami

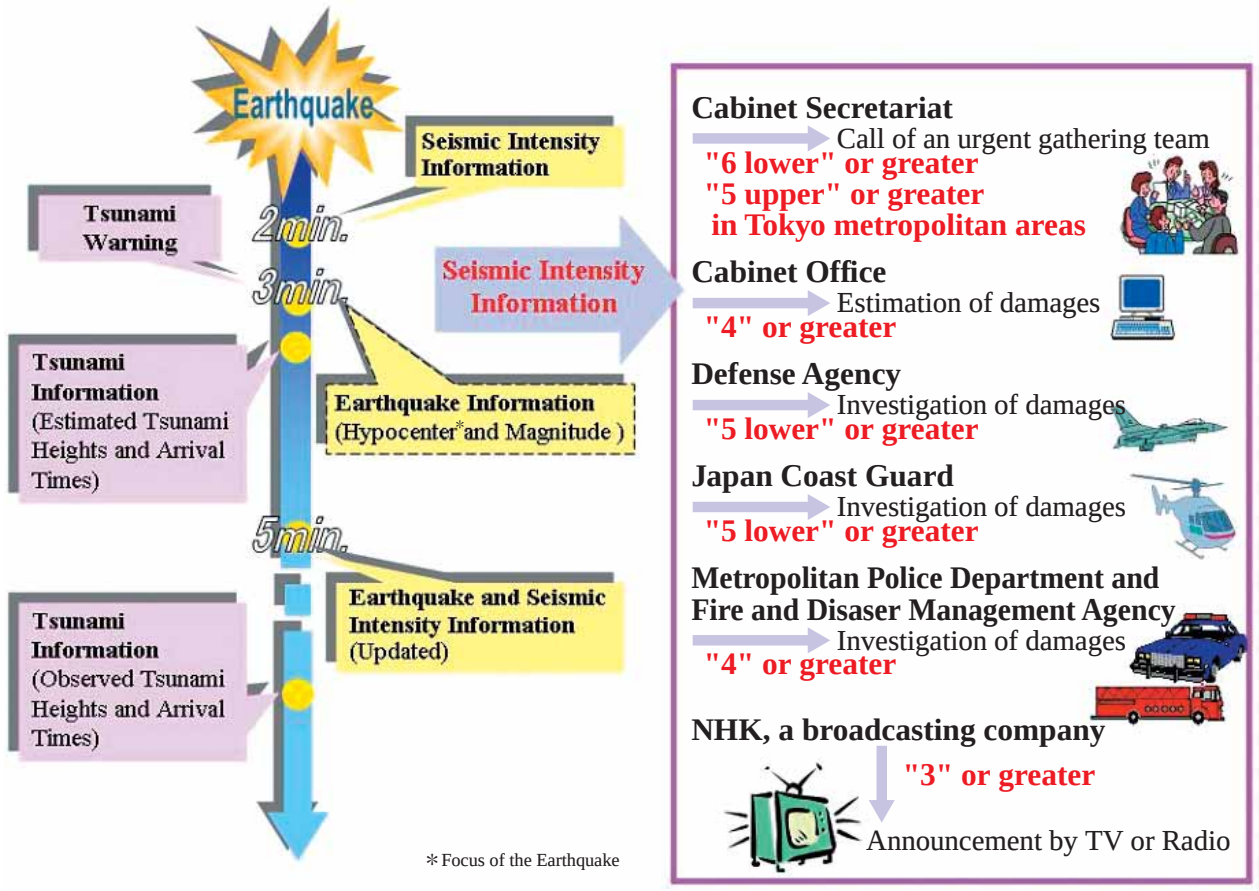
Japan is known as one of the most earthquake-prone countries in the world. More than 130,000 earthquakes occurred in 2005 around Japan including small ones which people do not feel. In 2004 and 2005, Japan suffered from serious damages from major earthquakes, such as "the Mid Niigata Prefecture Earthquake in 2004", which recorded seismic intensity 7 (in JMA scale Refer to Column in P.16) for the first time since "the South Hyogo prefecture Earthquake in 1995"; the earthquake of west-off Fukuoka Prefecture in 2005, which recorded seismic intensity 6 lower; the earthquake of off Miyagi Prefecture in 2005; etc. Earthquakes can occur and cause damages anywhere in Japan. Therefore, we should maintain ourselves to be prepared for earthquakes and take appropriate actions on occurrence of earthquakes.

JMA monitors seismic activities in and around Japan around the clock, and issues tsunami warning/information and earthquake information promptly when an earthquake occurs. In addition, JMA constructed a dense monitoring network around the Tokai area in cooperation with relevant organizations in order to detect the precursor of the great earthquake which is estimated to occur in the near future. If anomalous data is observed in the region, JMA will issue information on the Tokai Earthquake.

Warning and information issued by JMA is immediately disseminated to the public through disaster management authorities, local governments and mass media. The disaster management authorities and local governments take actions for mitigating disasters based on such warning and information.

As we look at overseas, we should still remember the devastating tsunami in the Indian Ocean in December 2004. JMA started providing tsunami information for countries in the Indian Ocean region in 2005, in addition to the Northwest Pacific region.

■ Information on Earthquake and Tsunami and its Application



Tsunami Warning/Information and Earthquake Information

Tsunami Warning & Information

Tsunami is generated when a large earthquake occurs shallowly under the ocean bottom or a huge landslide takes place near a coast. Tsunami has a great potential causing serious damages. However, if we can evacuate before the arrival of tsunami, we can save our lives.

JMA continuously monitors seismic activities throughout Japan around the clock and when an earthquake occurs, its hypocenter and magnitude are quickly calculated. If it shows that tsunami can be generated, tsunami forecast is issued immediately to call precaution. Tsunami forecast is categorized into two: Tsunami Warning (Tsunami height would be above 1.0m) and Tsunami Advisory (0.5m or less), and Warning is divided into two classes: Major Tsunami (3m or higher) and Tsunami (up to 2m), depending on the estimated tsunami height. JMA has defined 66 individual coastal regions which cover all of coastal areas of the country and issues Warning or Advisory for each region. In case tsunami is actually observed, JMA announces the observed data as tsunami information accordingly.

Tsunami is also generated in the Pacific areas far away from Japan such as around Chile or Alaska, some of which travel to and cause damage to Japan. Therefore, JMA also issues forecast and information on those tsunamis in close cooperation with the Pacific Tsunami Warning Center (PTWC) in Hawaii.

The tsunami forecast and information is disseminated among the public and ships rapidly through the disaster management authorities and mass media.

■ Tsunami Forecast and Information

<table>
<tr><td rowspan="4">Tsunami Forecast</td><td colspan="3">Issued in 3-5 minutes after the earthquake occurrence
Categorized by the estimated tsunami height</td></tr>
<tr><td colspan="2">Category</td><td>Estimated Tsunami Height
to be shown in the Forecast Message</td></tr>
<tr><td rowspan="2">Tsunami Warning</td><td>Major Tsunami</td><td>"3m", "4m", "6m", "8m", "10m or higher"</td></tr>
<tr><td>Tsunami</td><td>"1m", "2m"</td></tr>
<tr><td>Tsunami Advisory</td><td>Tsunami Attention</td><td>"0.5m"</td></tr>
<tr><td colspan="4">Information on estimated arrival time and height of tsunami for each coastal region</td></tr>
<tr><td colspan="4">Information on estimated time of high tide with tsunami arrival time at coasts</td></tr>
<tr><td colspan="4">Information on observed arrival time and height of tsunami</td></tr>
</table>

Column: Evacuate Immediately for Saving Your Lives from Tsunami

Evacuate from the seashore and riverside and take shelter to a high-altitude place (e.g. tall building, hill, etc.) immediately when:

1) a strong shake (seismic intensity 4 or greater) is felt;
2) a weak but long time and slow shake is felt; or
3) tsunami forecast is issued.

The statement in the box above contains very important knowledge that you should keep in mind for saving your lives from tsunami. For example, in case 1), the epicenter could be very close to the coast and a strong shake is felt, tsunami could arrive at the coast in a very short time before tsunami warning is issued. You should evacuate as soon as possible because tsunami closes up faster than humans run. When a warning or an advisory is issued, stop outdoor activities around the seashore or estuary such as sea bathing or fishing, and leave away. Only 0.5m tsunami is still strong so that humans could be dragged to offshore and injured by washed objects even when the tsunami goes out.

Quantitative Tsunami Forecast

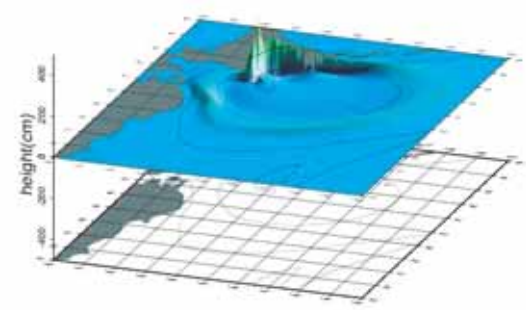
When tsunami is generated near a coast, it arrives at the coast in a very short time.

Therefore, JMA should issue tsunami forecast immediately after the occurrence of the earthquake.

JMA conducted tsunami simulation with computers in advance, for the assumed earthquakes of various locations and magnitude, and stored the results of tsunami arrival times and heights on a database, namely, tsunami database. When a large earthquake occurs, the operation system quickly calcurates the hypocenter and magnitude searches tsunami database referring to the calculated hypocenter and magnitude and picks up the most appropriate results from the database. Based on the estimated height of tsunami for each coastal region, JMA issues tsunami forecast.

This method enables JMA to work out both precise and rapid tsunami forecast operation.

■ Example of Tsunami Simulation



■ Example of Tsunami Forecast

■ 66 Coastal Regions

■ Example of Tsunami Forecast Message

津波予報　　平成１５年　９月２６日０４時５６分
気象庁地震火山部

津波予報をお知らせします
＊＊＊＊＊＊＊＊＊＊＊＊＊＊　見出し　＊＊＊＊＊＊＊＊＊＊＊＊＊＊
津波警報を発表しました
　北海道太平洋沿岸
これらの沿岸では、直ちに安全な場所へ避難してください
なお、これ以外に津波注意報を発表している沿岸があります
＊＊＊＊＊＊＊＊＊＊＊＊　津波予報の本文　＊＊＊＊＊＊＊＊＊＊＊＊＊＊
津波警報を発表した沿岸は次のとおりです
＜津波＞
　＊北海道太平洋沿岸東部、＊北海道太平洋沿岸中部
これらの沿岸では、直ちに安全な場所へ避難してください
津波注意報を発表した沿岸は次のとおりです
＜津波注意＞
　北海道太平洋沿岸西部、青森県日本海沿岸、青森県太平洋沿岸、岩手県、宮城県、福島県
以下の沿岸（上記＊印で示した沿岸）では直ちに津波が来襲すると予想されます
　北海道太平洋沿岸東部、北海道太平洋沿岸中部

Announcement of the Issuance of Tsunami Forecast

Issued Time

Coastal Regions where Warning is Issued

Coastal Regions where Advisory is Issued

Earthquake Information

When an earthquake occurs, JMA issues seismic intensity information in 2 minutes, which announces the occurrence of the earthquake and regions where the seismic intensity is equal to or greater than 3 in JMA Scale. Subsequently information on the hypocenter and magnitude of the earthquake and cities/towns/villages where a strong shake has been felt is issued.

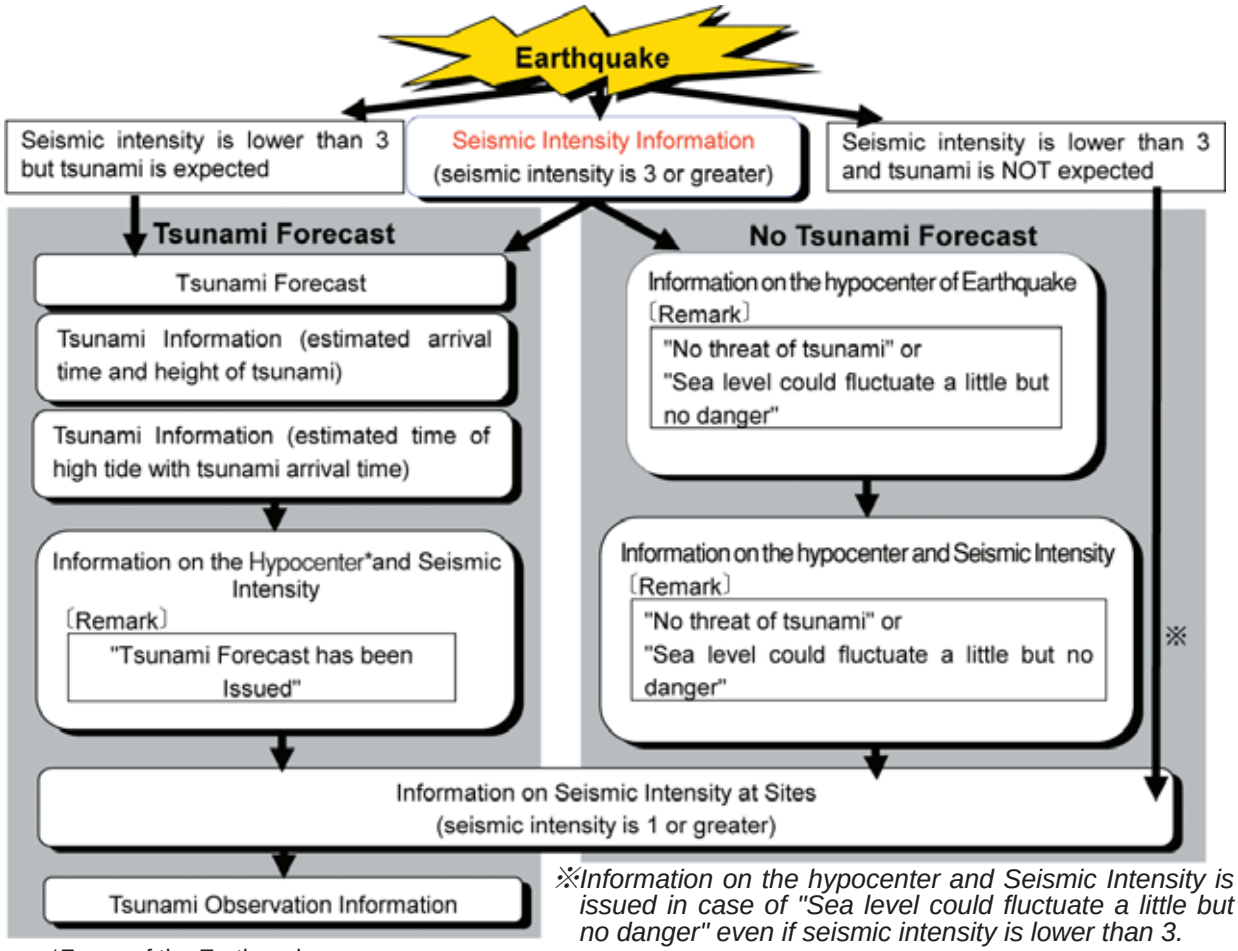
Since seismic intensity information is directly connected to the expected damages, therefore, this information is used as a trigger for disaster management authorities to take emergency measures.

In case earthquakes occur repeatedly, such as aftershocks of an large earthquake or earthquake swarm events, the number of the earthquakes is also announced.

■ Earthquake Information

	Contents
Seismic Intensity Information	Occurrence of an earthquake Regions of seismic intensity 3 or greater (Issued in 2 minutes after the earthquake occurrence)
Information on the hypocenter of Earthquake	Hypocenter and magnitude of the earthquake Remark of "No threat of tsunami" or "Sea level could fluctuate a little but no danger" (Issued when tsunami forecast is not announced)
Information on the hypocenter and Seismic Intensity	Hypocenter and magnitude of the earthquake Cities/Towns/Villages of seismic intensity 3 or greater and where the intensity is estimated as "5 lower" or greater but not reported from the seismic intensity meters
Information on Seismic Intensity at Sites	Hypocenter and magnitude of the earthquake Sites of seismic intensity 1 or greater
Information on Number of Earthquakes	Number of earthquakes which cause seismic intensity 1 or greater (Issued if earthquakes occur repeatedly)

■ Detailed Time Line on the Issuance of Information



*Focus of the Earthquake

※*Information on the hypocenter and Seismic Intensity is issued in case of "Sea level could fluctuate a little but no danger" even if seismic intensity is lower than 3.*

■ Example of Information on the Hypocenter and Seismic Intensity Message

地震情報（震源・震度に関する情報）　　平成１６年１０月２３日１８時７分
気象庁地震火山部発表

きょう２３日１７時５６分ころ地震がありました。
震源地は、新潟県中越地方（北緯３７．３度、東経１３８．８度）で、震源の深さは約２０ｋｍ、
地震の規模（マグニチュード）は６．８と推定されます。
［震度３以上が観測された地域］
震度６強 新潟県中越
震度５強 新潟県上越
震度５弱 福島県会津 群馬県北部 群馬県南部 埼玉県北部 新潟県下越 長野県北部
震度４　宮城県南部 山形県庄内 山形県村山 山形県置賜 福島県中通り 福島県浜通り 茨城県南部
栃木県南部 埼玉県南部 東京都２３区 新潟県佐渡 石川県能登 山梨県東部
震度３　宮城県北部 秋田県沿岸南部 山形県最上 茨城県北部 栃木県北部 埼玉県秩父 千葉県北東部
千葉県北西部 千葉県南部 東京都多摩東部 神奈川県東部 神奈川県西部 富山県東部
富山県西部 石川県加賀 長野県中部 長野県南部 静岡県伊豆
［震度５弱以上が観測された市町村］
震度６強 小千谷市
震度６弱 長岡市 十日町市 栃尾市 新潟中里村
震度５強 安塚町 中之島町 与板町 和島村 出雲崎町 小出町 六日町
震度５弱 只見町 西会津町 福島柳津町 片品村 高崎市 北橘村 久喜市 上越市 浦川原村 新潟栄町
湯之谷村 広神村 巻町 三水村
［震度５弱以上と考えられるが現在震度を入手していない市町村］
松代町 松之山町 牧村 柿崎町 頸城村 新潟吉川町 三和村 三条市 柏崎市 加茂市 見附市 越路町 新潟
三島町 山古志村 川口町 堀之内町 守門村 入広瀬村 塩沢町 新潟大和町 新潟川西町 津南町 高柳町
新潟小国町 刈羽村 西山町 燕市 白根市 岩室村 弥彦村 分水町新潟吉田町 月潟村 中之口村
この地震による津波の心配はありません。
情報第２号=

Issued Time

Hypocenter and Magnitude

Regions of seismic intensity 3 or greater

Cities/towns/villages of seismic intensity 3 or greater

Cities/towns/villages where seismic intensity "5 lower" or greater is estimated but not reported by seismic intensity meters

Remark "No threat of tsunami"

Estimated Seismic Intensity Distribution Map

Scale of ground motion is critically affected by the surface geology. For example, ground motion is amplified on a soft ground. JMA analyzes seismic intensity, taking into account of such amplification, for every 1km grid space and draws Estimated Seismic Intensity Distribution Map.

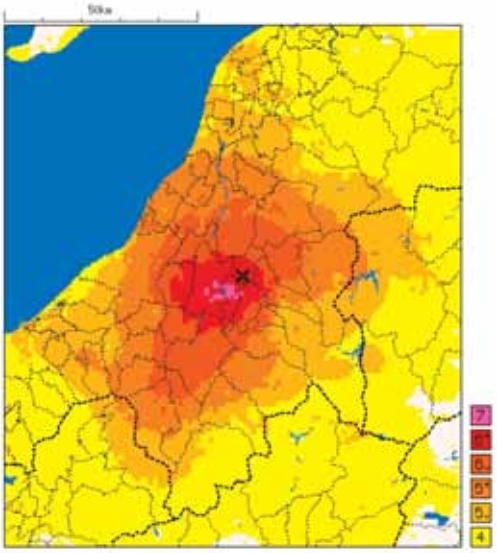
The Map is helpful for grasping the distribution of areas where the strong motion should have taken place. When seismic intensity "5 lower" or greater is observed, JMA provides the Estimated Seismic Intensity Distribution Map to the related organizations such as local governments and mass media. The Map is also put in the JMA website.

The figure left below is an example of the Estimated Seismic Intensity Distribution Map. This is for "the Mid Niigata Prefecture Earthquake in 2004" and derived from observed seismic intensity data shown in the figure right below. We can see that the area of "6 lower" or greater extends over the several cities/towns/villages around the middle Niigata region.

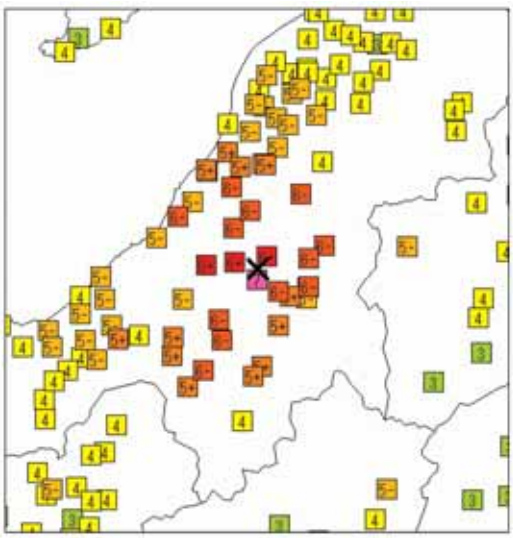
The analyzed values have a margin of errors, therefore, users should focus their attention on the extent and distribution of areas of strong ground motion rather than estimated values at each grid.

The Mid Niigata Prefecture Earthquake in 2004

■ Estimated Seismic Intensity Distribution Map



■ Observed Seismic Intensity Values



Information about Tokai Earthquake

Prediction and Information on Tokai Earthquake

In the Tokai region, it is not thought to be surprising if a large-scale earthquake with a magnitude around 8 (Tokai Earthquake) will occur anytime. In order to predict the occurrence of this Tokai Earthquake, JMA constructed seismic and crustal deformation observation networks in cooperation with the related organizations, and is observing them around the clock (refer to p.19). When anomalous data are observed, JMA issued "Information about Tokai Earthquake" for the preparatory action and the earthquake disaster prevention emergency measures. This information consists of three kinds; Tokai Earthquake Report, Tokai Earthquake Advisory, and Tokai Earthquake Warning.

"Tokai Earthquake Report"

This is issued when the observed phenomena cannot be evaluated at once whether it is a precursor of Tokai Earthquake or not. No special countermeasure is needed when this information is issued.

"Tokai Earthquake Advisory"

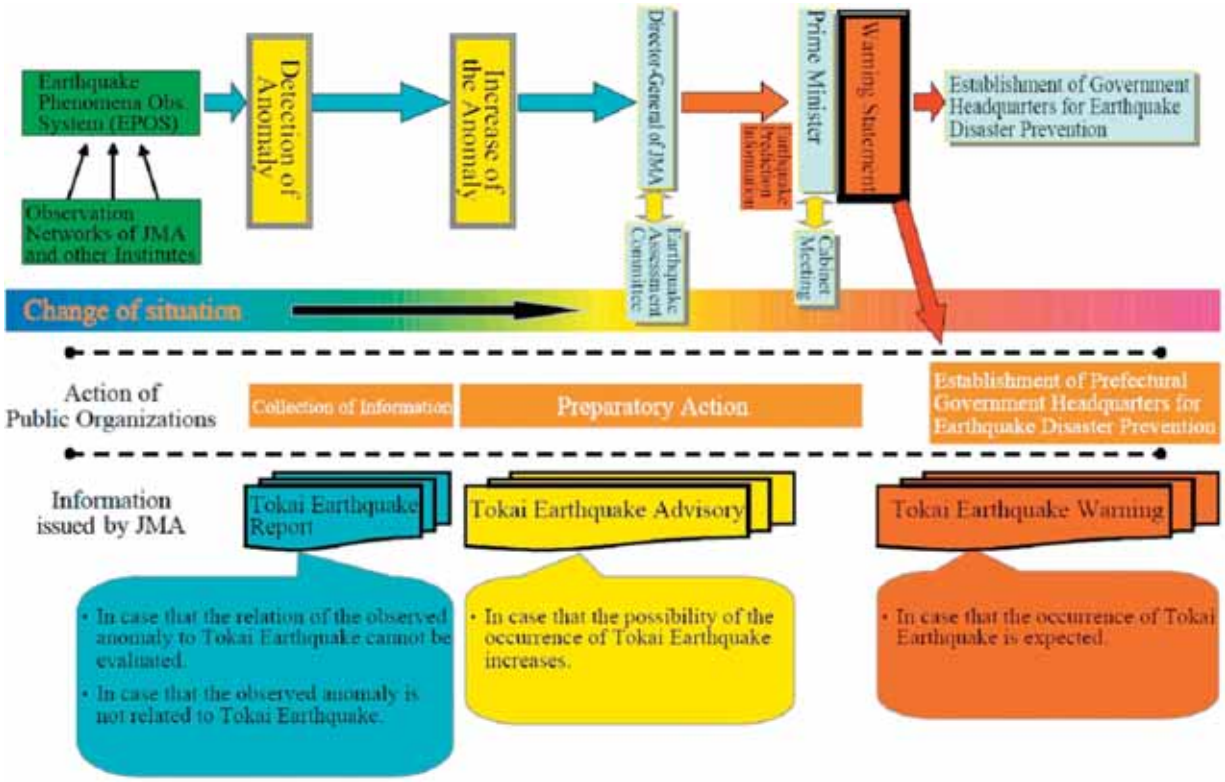
This is issued when the possibility that the observed phenomena are precursors of Tokai Earthquake increases.

When this information is issued, some organizations related to disaster prevention begin to prepare for Tokai earthquake. Some schools and companies make students and staffs go home. Follow on the notice from the government concerning disaster prevention and/or the disaster management plan provided beforehand by local governments.

"Tokai Earthquake Warning"

This is issued when the occurrence of Tokai Earthquake is expected, based on the examination of "Earthquake Assessment Committee for Areas under Intensified Measures against Earthquake Disasters" consisting of specialists of earthquakes. This is issued almost at the same time that the Prime Minister issued the Warning Statement. A serious alert is constructed hereby this Warning Statement. Pay enough attention to the occurrence of Tokai Earthquake, and act on the disaster management plan provided beforehand by the municipality.

■ Flow of Information about Tokai Earthquake



Notes: English version of "Information about Tokai Earthquake" is not available on web -page as of June, 2006.

■ Sample of "Information about Tokai Earthquake"

東海地震注意情報平成○年○月○日　　××時××分
気象庁地震火山部

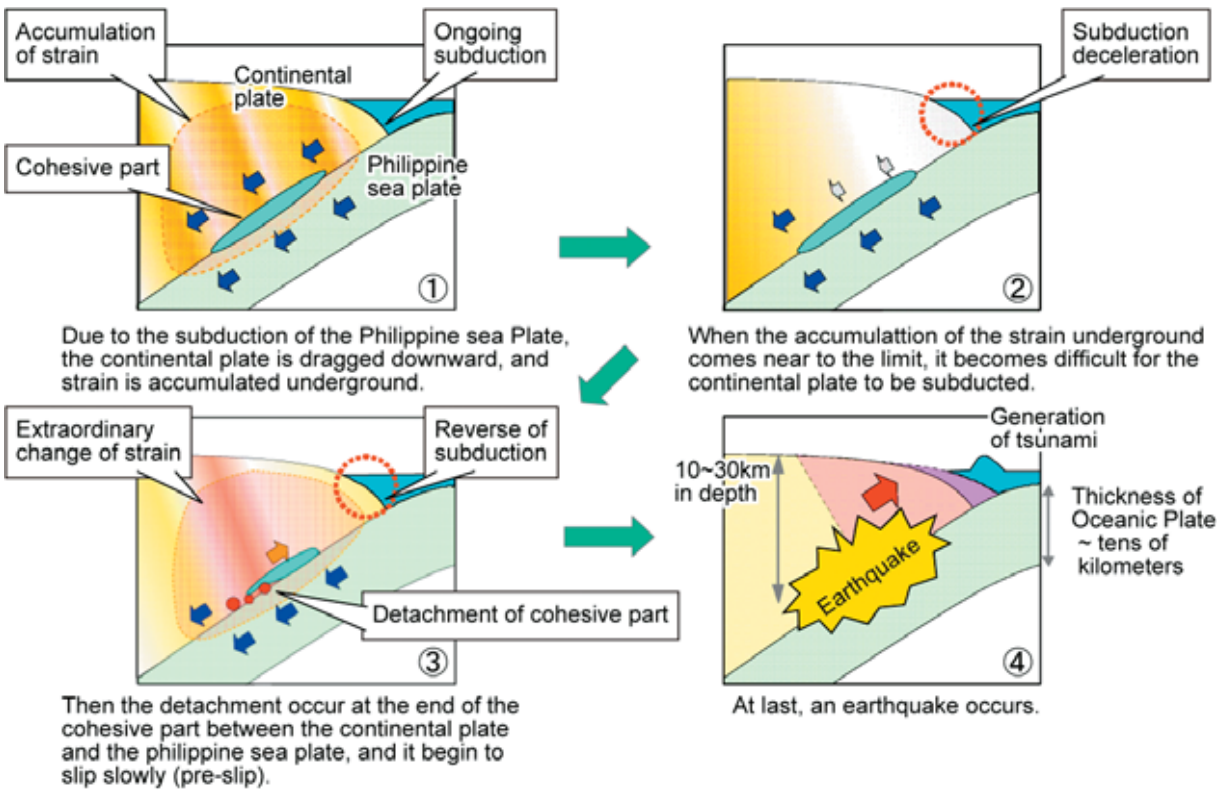
＊＊　見出し　＊＊
　地震防災対策強化地域及びその周辺地域においては、東海地震の発生に注意が必要です。
静岡県中部及び西部の地殻変動データの一部に変化が現れています。この変化は、東海地震の前兆すべりの発生に伴うものである可能性が高くなっています。

＊＊　本文　　＊＊
　東海地域に設置されている歪（ひずみ）計のうち、榛原（はいばら）観測点のデータに本日０８時頃から明瞭な変化が見られるようになり、変化はその後加速しながら続いています。本日０９時頃からは、川根（かわね）観測点のデータにも明瞭な変化が現れています。また、本川根（ほんかわね）観測点のデータの変化も続いており、周辺の傾斜計、水位計にも若干の変化が見られるようになりました。
　現在、榛原、川根の観測点等で観測されている変化の量と傾向は、プレート境界の一部がゆっくりとずれ動く場合にも、観測される可能性があるものです。気象庁は、地震防災対策強化地域判定会委員の意見等も踏まえ、これらの変化が、東海地震の前兆すべりの発生に伴うものである可能性が高くなったと判断しました。
　地震防災対策強化地域及びその周辺地域においては、東海地震の発生に注意が必要です。
　気象庁では、他の観測点も含め、観測データの推移を厳重に監視しています。

　状況に特段の変化がない限り、次の情報発表は本日１３時００分を予定しています。

Column : What is "pre-slip"?

Pre-slip is a phenomenon that a part of the source area (in case of Tokai Earthquake, this is a cohesive part of the plate boundary) is detached slowly and begins to slip and move before an earthquake occurs. It is conceivable that the precursory phenomenon as a key for the prediction of Tokai Earthquake would be this pre-slip. Japan Meteorological Agency is trying to catch the pre-slip with the strain meters installed in the Tokai region.



Scenario of Tokai Earthquake Occurrence

Tokai Earthquake is considered to pass through this course; ①strain accumulation, ②subduction deceleration, ③pre-slip, ④earthquake occurrence. This scenario is named Pre-Slip Model. Japan Meteorological Agency attempts to predict Tokai Earthquake by detecting the anomalous crustal deformation phenomena accompanied by the pre-slip.

Information on aftershocks of large earthquake

What is Aftershock?

When a large earthquake occurs, a sequence of smaller earthquakes usually follows it. The largest earthquake is called "mainshock", and the smaller ones are "aftershocks".

When a mainshock causes damage, people should stay clear of damaged houses or flimsy cliffs for 1 week to 10 days in general (for more than 1 month when the aftershocks are quite active). The number of aftershocks decreases and the magnitude of them gradually becomes smaller as time passes after the mainshock. In some cases, however, relatively large aftershocks occur in the sequence.

It takes a long time until the aftershock sequence comes to an end. Aftershocks of The Southern Hyogo Prefecture Earthquake (Kobe Earthquake, 1995), for example, sometimes still occur now, and the aftershocks that are large enough to be felt by human are observed several times a year.

Prospect of Aftershock Activity

When a large earthquake occurs, JMA announces to the public about the aftershock activity and the need to pay attention to the activity.

In case additional damages by the continuous aftershocks are expected, JMA announces the prospect of the aftershock activity. The conditions for issue of these alerts are,

[1] Heavy damage is caused by the mainshock [for example, seismic intensity (JMA scale) of "6 lower" or greater are observed],

[2] Damage is observed in a large area [for example, area of seismic intensity "5 lower" or greater is large],

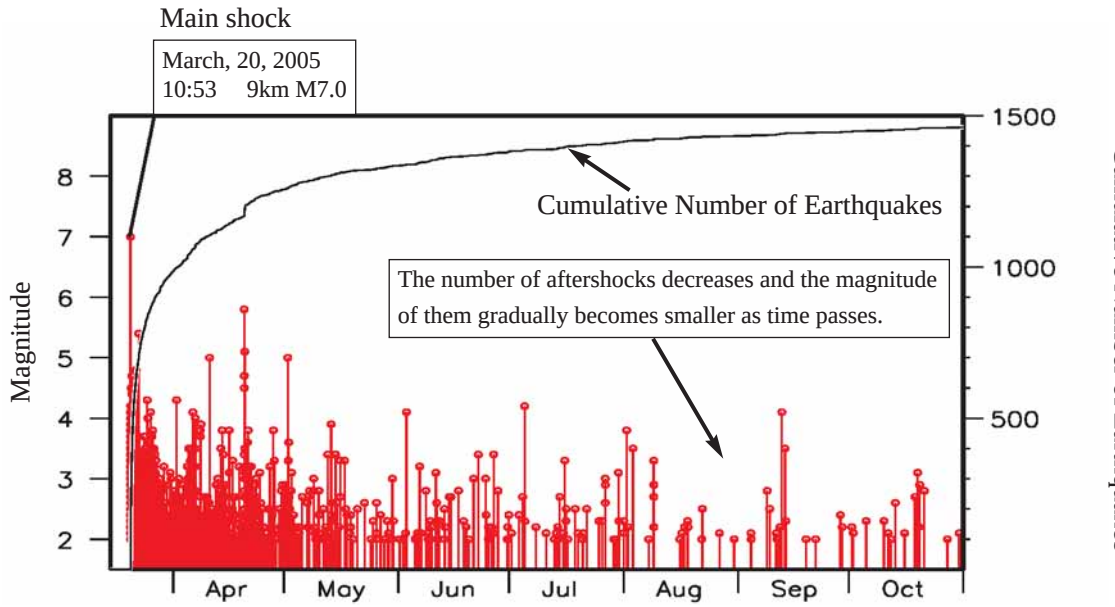
[3] Many aftershocks are large enough to be felt by human occur frequently.

The first announcement of the prospect is issued after making sure that the behavior of activity is mainshock- aftershock sequence, which is normally 1 day after the mainshock.

The prospect contains (a) how is the activity as compared with past ones, (b) how is the current activity, (c) how long attention should be paid to the aftershocks, (d) how large seismic intensity is expected for the aftershocks, and (d) what we should be careful of. The aftershock forecast using the probability representation is also included in the prospect.

The information of prospect is published from mass media, that is, TV, radio and newspaper, and also on the web-page of JMA.

■ Aftershock Sequence of the earthquake occurred west-off Fukuoka Prefecture in March, 2005



Height of vertical bar represents magnitude of the earthquake. Aftershocks occur frequently and some of them have large magnitude just after the mainshock, but the number of aftershock gradually decreases, and also the magnitude of them becomes smaller by lapse of time.

■ Example of the prospect of aftershock activity (An image on the web-page of JMA)

Notes: English version of "Prospect of Aftershock activity" is not available on web - page as of June, 2006.

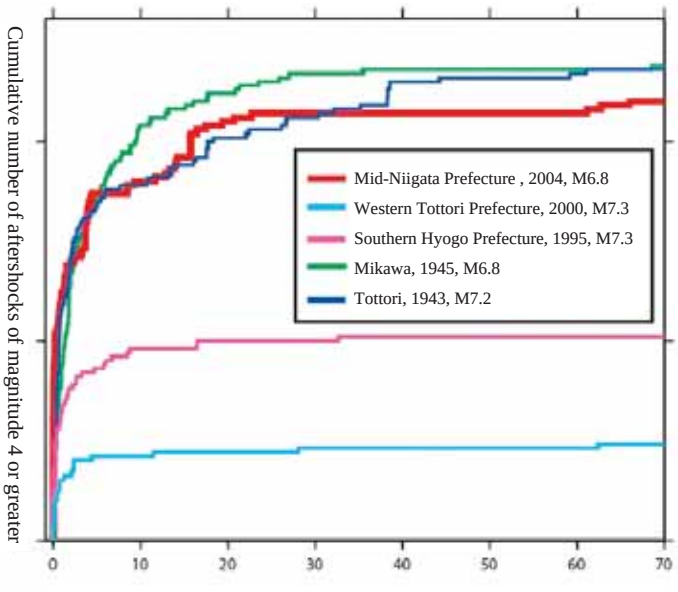
Column: Aftershock

Just after the large earthquake, a rumor may be heard: "Larger one will occur". Because many people are quite nervous after such frightening experience of the large earthquake, the rumor may cause confusion among them.

Seismic activity is classified according to its pattern, for example, mainshock-aftershock type and swarm type. If the activity continues keeping mainshock-aftershock behavior, earthquakes larger than the mainshock hardly occur. If the rumor is upsetting, it is recommended to refer the prospect issued by JMA.

There are various sequences for aftershock activity even if it is mainshock-aftershock type. Right figure shows time variation of the cumulative number of aftershocks with magnitude 4 or greater for several earthquakes. The number does not simply depend on the magnitude of the mainshock, and varies from activity to activity. For the aftershock activity of the Mid-Niigata Prefecture Earthquake on October 23, 2004, a large number of aftershocks with magnitude 4 or greater were observed as compared with past large earthquakes.

Aftershock activity of major inland earthquakes in Japan



Comparison of cumulative number of aftershocks of magnitude 4 or greater for major inland earthquakes in Japan.

From the point of view of the number, activity of aftershocks of the Mid-Niigata Prefecture Earthquake of 2004 is the twice of that of the Southern Hyogo Prefecture Earthquake (The Kobe earthquake, 1995) in spite of its small magnitude.

International Tsunami Information Service

Northwest Pacific Tsunami Advisory

The Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS), which was formed in 1966 under the Intergovernmental Oceanographic Commission (IOC) of the UNESCO, proposed that the role of the regional center in the Northwest Pacific region could be taken by JMA in order to supplement and enhance the capability of the Pacific Tsunami Warning Center (PTWC), which covers all over the Pacific in tsunami watch as the primary center of the PTWS.

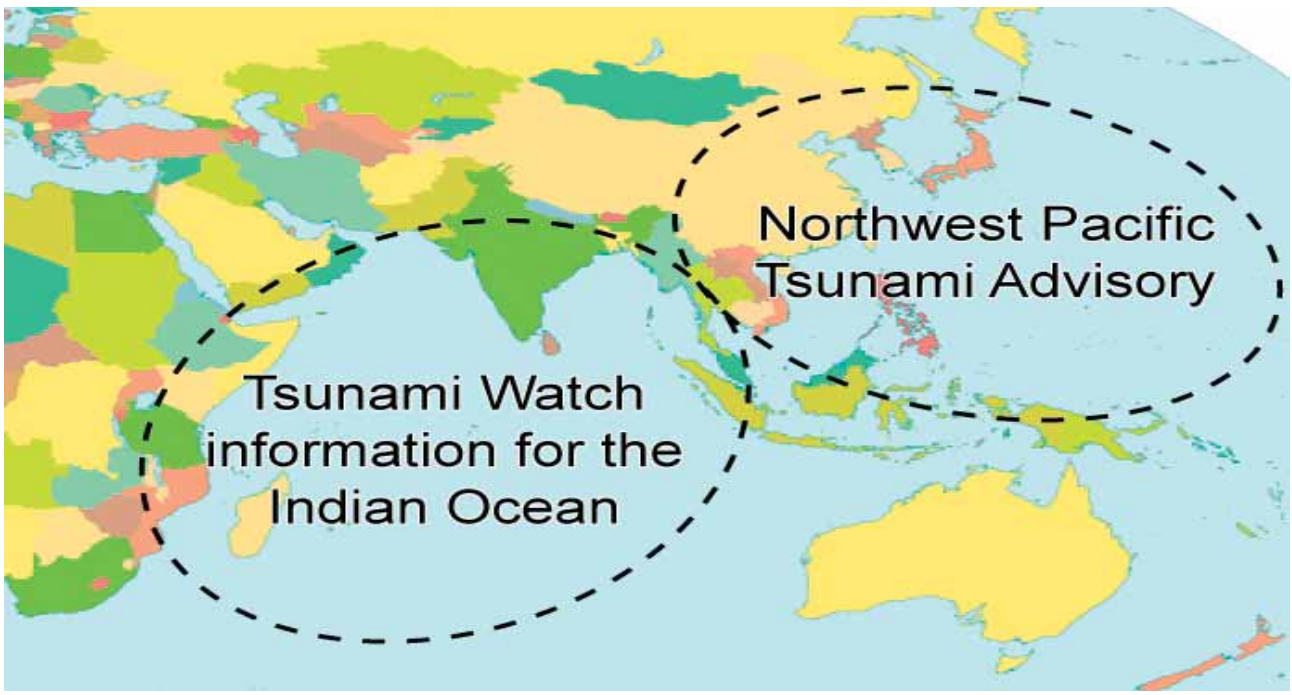
In response to this international request, JMA initiated providing tsunami forecast for earthquakes which occur in the Sea of Japan to the relevant countries in January 2001. In March 2005 JMA established the Northwest Pacific Tsunami Advisory Center (NWPTAC) and started to provide tsunami advisories for earthquakes in the Northwest Pacific region.

Tsunami Watch Information for Indian Ocean

The unprecedented tsunami triggered by the huge earthquake of west off Sumatra on 26 December 2004 (M9.0) brought enormous damage to the countries around the Indian Ocean. With it as a turning point, countries in the Indian Ocean region took steps to establish a system to reduce damages caused by tsunami and, therefore, the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) was formed in June 2005.

However, it is supposed to take some years before the system in Indian Ocean becomes fully operational. In the meantime, on an interim basis in case of large earthquake occurrence again, JMA provides the Tsunami Watch Information, in close cooperation with PTWC, for the Indian Ocean countries since March 2005.

■ Coverage Area for the Northwest Pacific Tsunami Advisory and Tsunami Watch Information for the Indian Ocean



The Northwest Pacific Tsunami Advisory (NWPTA) and the Tsunami Watch Information (TWI) is issued in case that an earthquake of M6.5 or greater occurs in the respective coverage areas, and contains the origin time, hypocenter and magnitude of the earthquake and, if it is expected to generate tsunami, estimated arrival time and height of tsunami (as for NWPTA) or estimated travel time of tsunami (as for TWI). When tsunami is observed at any sea level monitoring station, the observed result is also provided.

Earthquake Early Warning

Motivation for Development of EEW

If we were informed of the strong ground motion arrival beforehand, we could take some actions to protect ourselves in the meantime even only several or several-tens seconds. JMA has developed the Earthquake Early Warning (EEW) technology to address this issue.

Principle

Seismic wave consists of primary wave (P-wave) and secondary wave (S-wave). S-wave contains high amplitude and causes damage, but it propagates slower than P-wave. When P-wave arrives firstly at a seismic station close to the epicenter, the EEW system quickly determines the hypocenter and magnitude of the earthquake by a few seconds of P-wave data at the station, and estimates arrival time of S-wave and seismic intensity at each place. The estimated information is aimed to be provided before the S-wave arrival.

EEW is expected to be used for taking actions to mitigate damages, e.g. emergency stop for trains and elevators, actions for avoiding danger, etc.

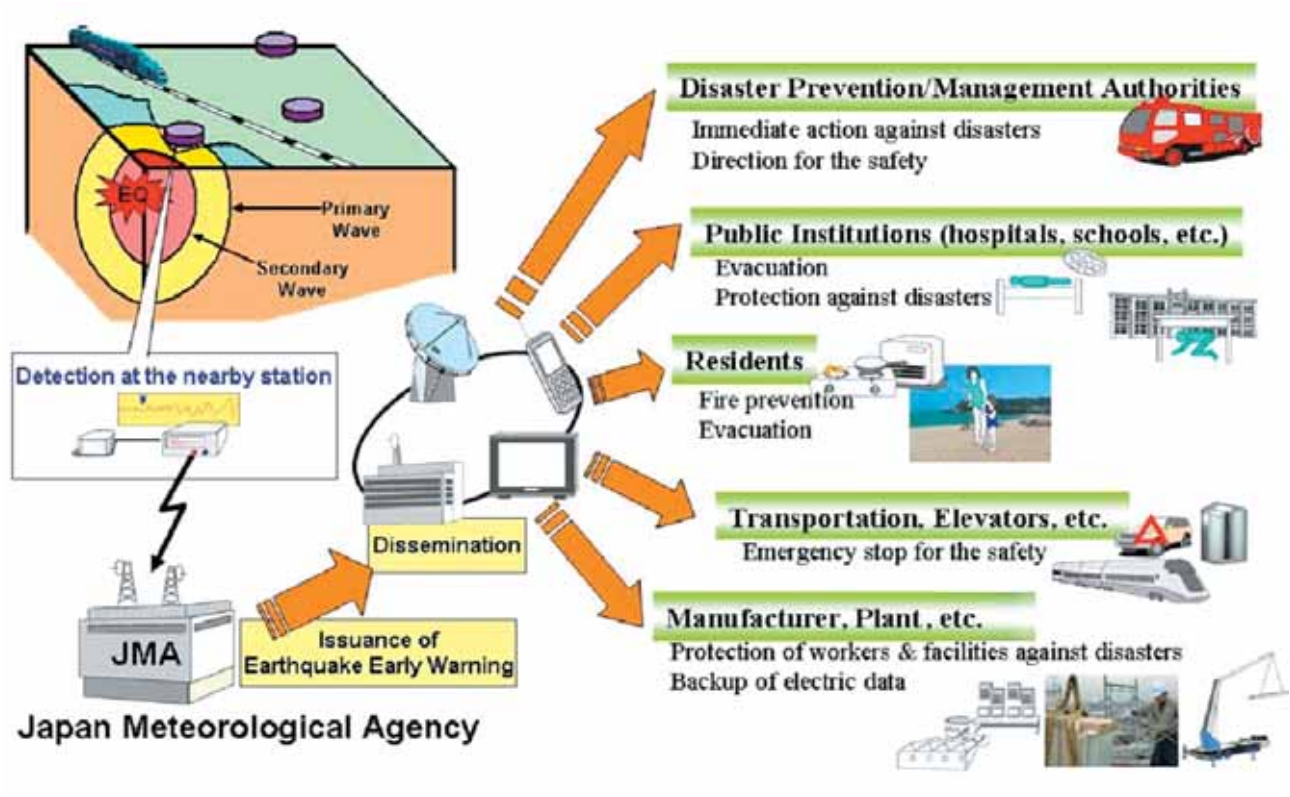
Feature of EEW

The elapsed time from EEW issuance to the S-wave arrival is very short, ten and a few seconds at longest depending on geographical location of hypocenter. If an earthquake occurs in land area, people directly above the hypocenter will receive EEW after the S-wave arrival.

As more stations detect seismic waves, the system produces more accurate EEW. EEW users receive updated EEW messages one after another in a very short time.

As mentioned above, EEW has quite different nature from other earthquake information which is already familiar to people. Therefore, users are invited to fully understand the nature and limit of EEW for an appropriate and effective use.

■ Application of EEW

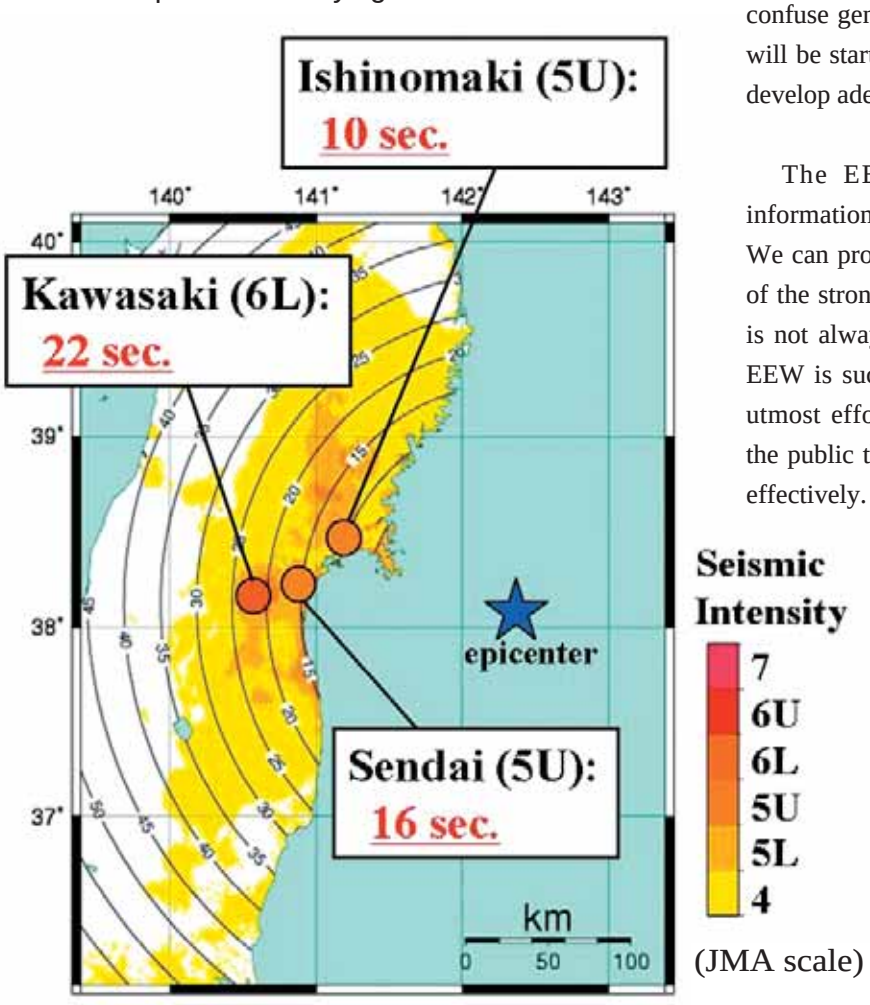


EEW in Actual Case

The figure below shows elapsed time from EEW issuance to arrival of S-wave in the case of the earthquake of off Miyagi Prefecture in 2005 (M7.2). The first EEW message was issued in 4.5 seconds after the closest seismic station (Ishinomaki) detected the earthquake. For example, there remained 16 seconds before the S-wave arrival in Sendai City. We should keep in mind that this elapsed time is just for this event. Elapsed time varies depending on a number of conditions such as the location of hypocenter. We should also take into account that it takes some time for transmission of the EEW message.

As for earthquakes which occur in land area, elapsed time is often shorter than that of earthquakes in the sea.

■ Elapsed time from EEW to S-wave; Earthquake off Miyagi Prefecture in 2005



1st EEW
Issued 4.5 seconds after the detection of seismic wave.
Elapsed Time:
22 sec at Kawasaki (6 lower)
16 sec at Sendai (5 upper)
10 sec at Ishinomaki (5 upper)

Operational Aspect

JMA installed new seismometers which support the EEW system. In February 2004 JMA started to provide EEW messages for limited organizations on a trial basis and has examined how to use EEW appropriately in cooperation with relevant organization. The examination includes application in automatic control system such as deceleration of trains and emergency stop for elevators, people's actions for avoiding danger, and communication system to transmit EEW messages such as cellular phones and satellite.

Before we move on to the official operation of the EEW service, JMA has established a committee comprised of experts and representatives of governmental/public organizations concerned to discuss modalities of provision and application of EEW. Based on the discussions at the committee, JMA is going to officially provide EEW to the limited organizations which are considered to be familiar with EEW and their application can be regarded not to confuse general public. The service for general public will be started after campaigns to a sufficient extent to develop adequate public awareness.

The EEW technology enables us to obtain information on earthquakes much earlier than before. We can protect ourselves by taking actions in advance of the strong motion arrival. On the other hand, EEW is not always issued before the strong motion arrival. EEW is such a new information. JMA will make its utmost efforts for promoting better understanding of the public through the campaigns so that EEW is used effectively.

Rapid and Assured Dissemination of Information

Data Collection and Processing System

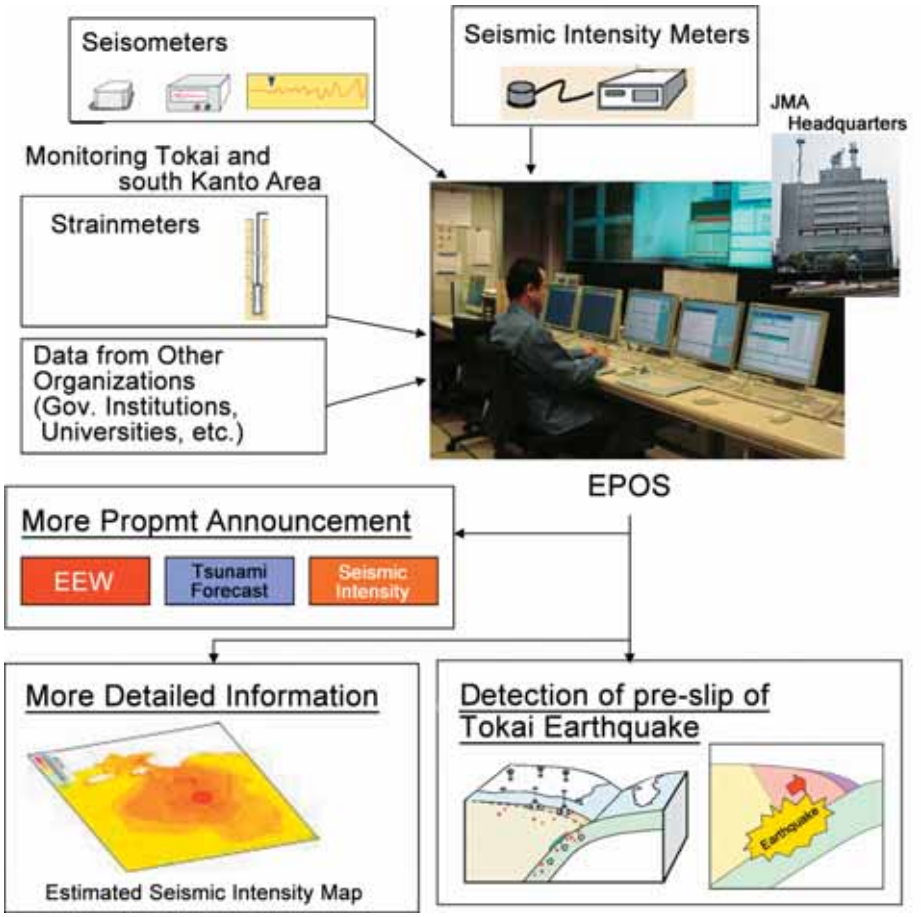
JMA has developed data-collection, processing and communication system for monitoring seismic activities and issuing warning/information, which is directly connected to disaster prevention and mitigation countermeasures. With this state-of-the-art computer system, JMA conducts tsunami warning and earthquake information service around the clock.

This comprehensive system is composed of one central system and five local systems. The central one, which is called EPOS (Earthquake Phenomena Observation System) and installed at the JMA headquarters, is responsible for issuing tsunami warning for the central part of Japan, nationwide earthquake information and information about Tokai Earthquake. The other local systems, which are called ETOS (Earthquake and Tsunami Observation System) and installed at the District Observatories in Sapporo, Sendai, Osaka, Fukuoka and Okinawa, are responsible for issuing tsunami warning and earthquake information for each district.

Assured Communication

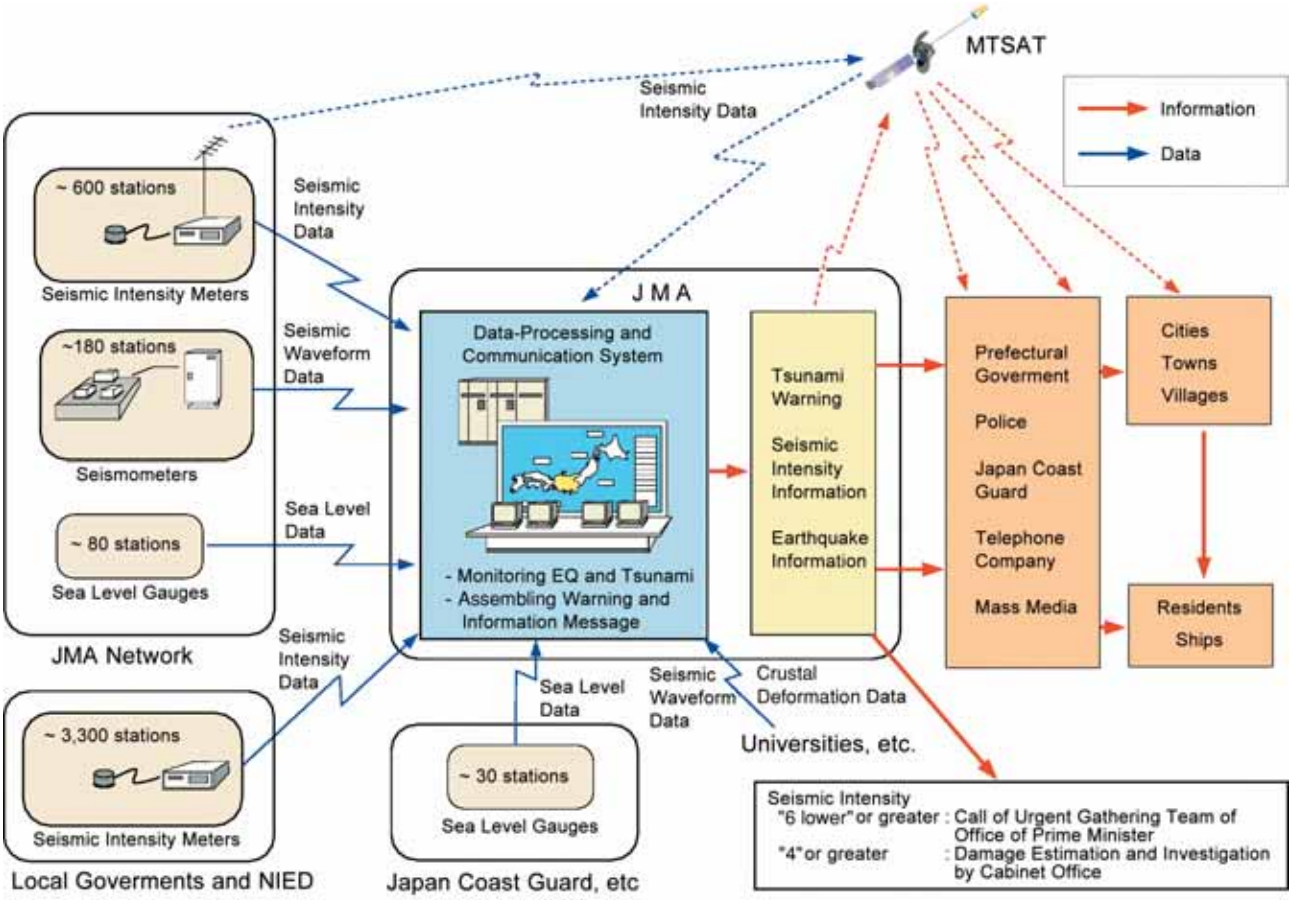
JMA transmits various warning and information to disaster management authorities, local governments and mass media online over the computer network across the country. Such warning and information is quickly disseminated among the general public via those recipient organizations.

Tsunami warning, earthquake information and information about Tokai Earthquake should be disseminated not only urgently but also surely in order neither to miss nor to be late in carrying out countermeasures in a timely manner in case of emergency. The JMA's system is designed to have redundant paths and machines for continuous operation.



Especially in case of a massive earthquake, the informaiton should be disseminated much more surely. JMA applies a scheme to avoid congestion of the communication lines and uses the MT-SAT communication function as a back-up line, so that JMA can collect data and disseminate warning and information even in the middle of major disaster.

■ Data Collection and Dissemination of Information



Column: Access to Warning and Information issued by JMA

JMA endeavor to disseminate tsunami warning and earthquake information rapidly and assuredly. JMA's system has functions of monitoring the connection status of online communication. With this sytem, JMA is watching whether the line is connecting and recipients can get the warning and information.

JMA puts warning and information in the website (http://www.jma.go.jp). However, it does not always ensure the quick dissemination of warning and information because you can not notice it until you access to the site. In addition, the Internet could be congested and the site could be stuck in case of massive earthquake. It is recommended to obtain emergency information, such as tsunami warning, from TV, radio or local governments. In this regard, it is also recommended that you carry a portable radio with you in order to get information at anytime when you go out for leisure near the sea such as fishing.

Earthquake and Tsunami Monitoring Network

Seismometer Network

JMA operates seismic network which consists of about 180 seismometers and collects seismic waveform data in real-time around the clock. When a large earthquake occurs, JMA quickly determines hypocenter and magnitude of the earthquake using the collected seismic data and issues tsunami warning and earthquake information.

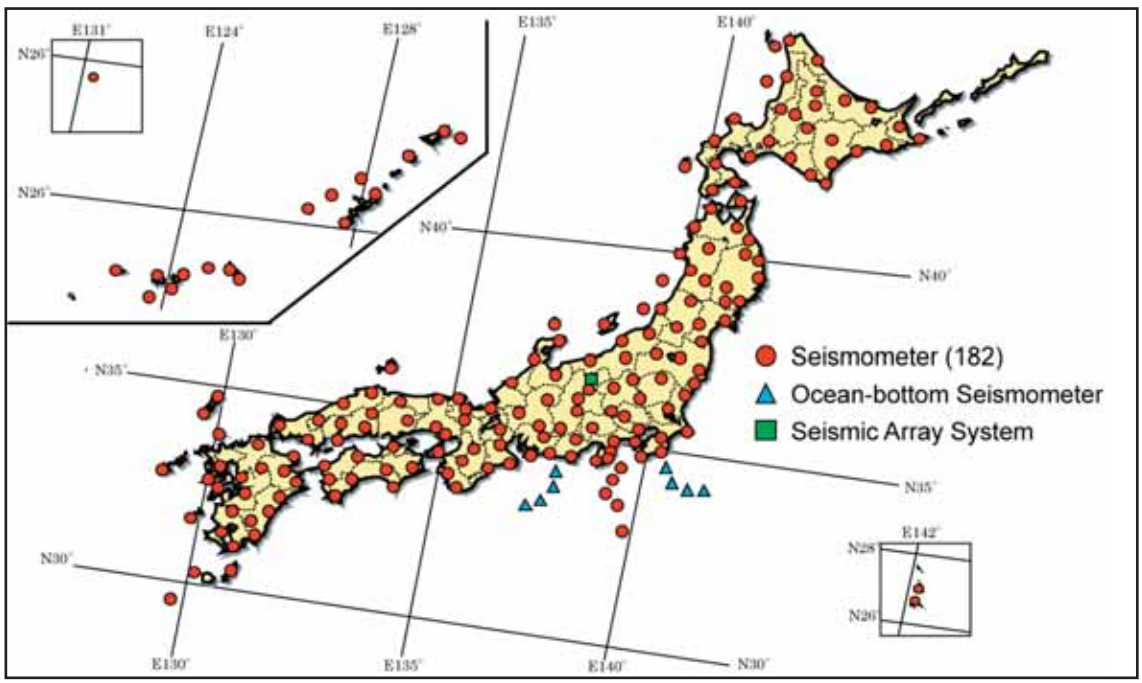
JMA also collects and analyzes seismic data from universities and disaster management research institutes such as the National Research Institute for Earth Science and Disaster Prevention (NIED) in order to conduct a comprehensive assessment on seismic activities for promotion of research activities in cooperation with the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The products of this analysis are shared with relevant organizations.

■ JMA Seismic Station

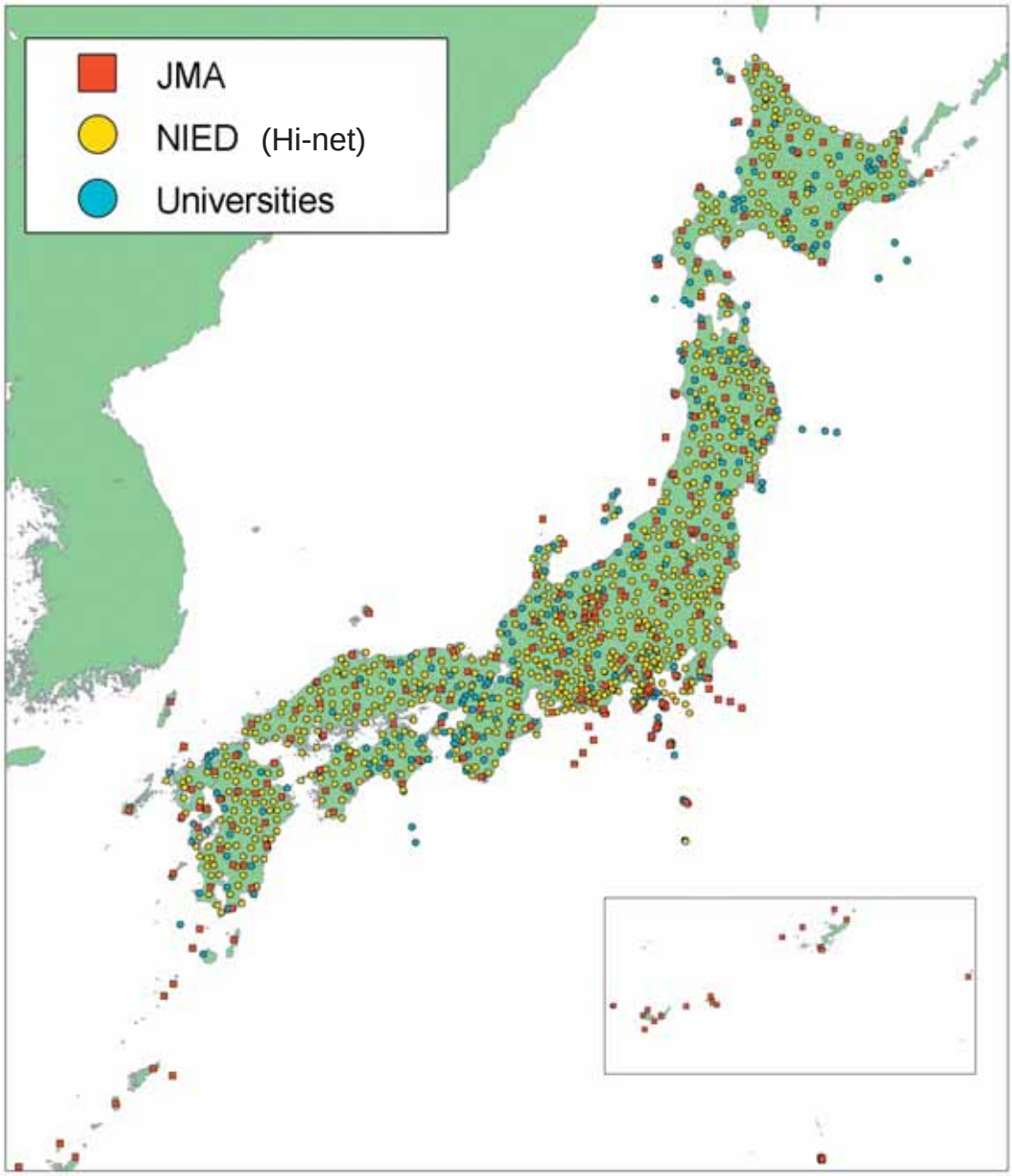
Communication Facilities in Shelter

Seismometer and Seismic Intensity Meter in Box

■ JMA Seismometers Network



■ Seismometers Network in Japan



Column: Magnitude and Seismic Intensity

"Magnitude" is a numerical value which represents the scale of a fault slip underground. When the seismic wave released from the fault reaches the land surface, we feel a ground motion. "Seismic intensity" represents the scale of the ground motion at the land surface.

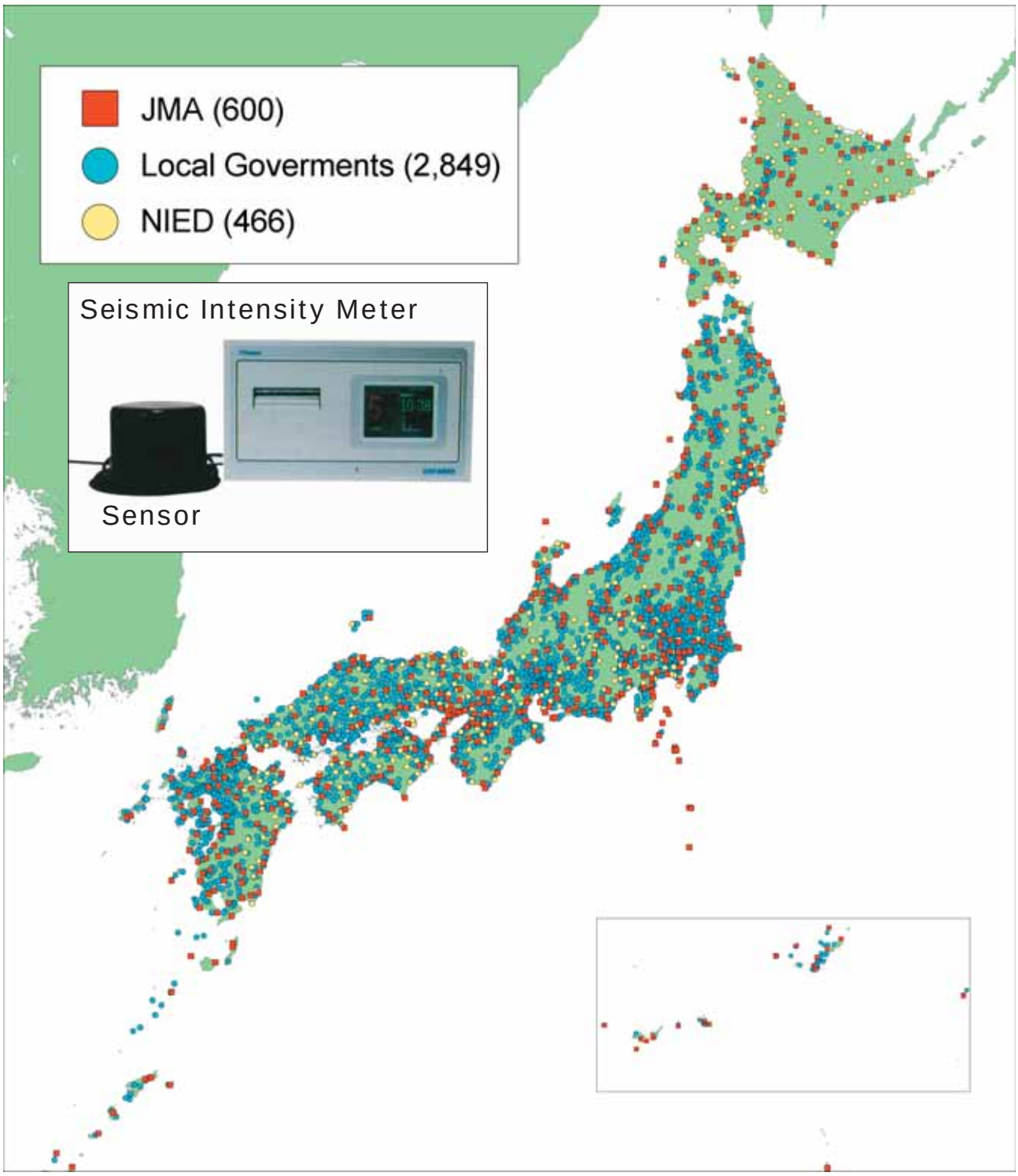
Magnitude (Richte Scale) : Magnitude is an indicator of the scale of an earthquake and often represented as "M". M is calculated from the maximum amplitude of the seismic wave recorded by seismometers. One increase of M means that the energy of earthquake increases thirtyfold.

Seismic Intensity : Seismic Intensity is an indicator of the scale of the ground motion caused by an earthquake and measured by seismic intensity meters. The seismic intensity (JMA scale) is divided into 10 scales, namely, 7, 6 upper, 6 lower, 5 upper, 5 lower, 4, 3, 2, 1 and 0 in order from the strongest to the weakest. People feel a shake in greater than scale 1, buildings are damaged in 5 upper and serious damage is caused in 6 upper.

Seismic Intensity Network

JMA installed about 600 seismic intensity meters throughout the country. In addition, JMA collects seismic intensity data from other 3,300 stations operated by local governments and the National Research Institute for Earth Science and Disaster Prevention (NIED). When an earthquake occurs, JMA promptly issues seismic intensity information based on the data obtained at those stations. The seismic intensity information is used by disaster management authorities as reference for their initial actions in emergency.

■ Seismic Intensity Meters used for Information issued by JMA



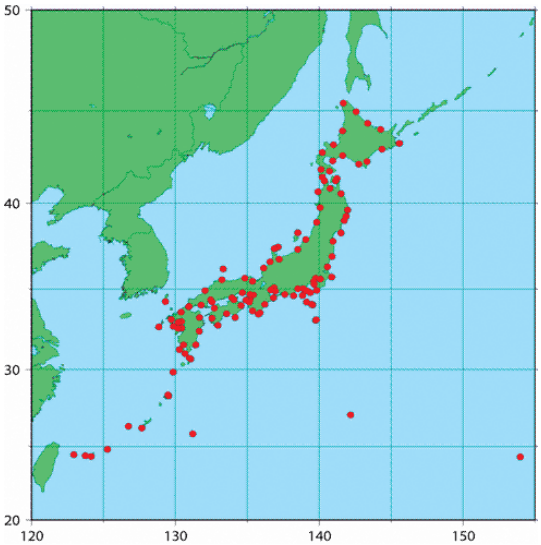
Tsunami Monitoring Network

JMA operates about 80 tidal gauge stations and collects real-time sea level data from about 100 stations including those operated by relevant organization such as the Japan Coast Guard. The observed data is used for issuing tsunami observation information, re-evaluating and canceling tsunami forecast.

Sea level data is also used for examining and identifying the nature of earthquakes and tsunamis (e.g. location of tsunami source can be derived from analysis of arrival time of tsunami at coasts).

■ Stilling-well Type Gauge Station

■ Tide Gauges for Monitoring Tsunami



■ Acoustic Type Gauge Station

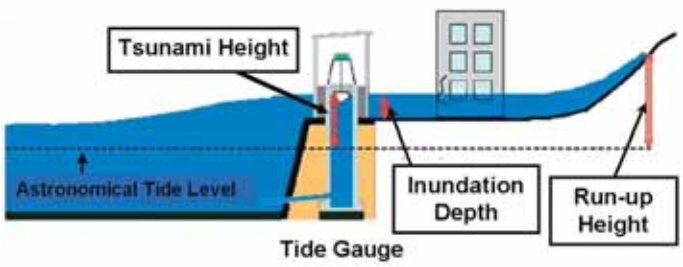
Column: Tsunami Observation

"Tsunami height" or "tsunami amplitude" in JMA message is the change of sea level caused by tsunami from astronomical tide level.

Unlike wind wave, tsunami is a movement of the whole of sea water from the surface to the bottom, and possesses huge energy so that it is not attenuated at coasts and runs up into far inland. The altitude where the tsunami front reaches is called "tsunami run-up height." Tsunami run-up height reaches several times higher than the tsunami height at the coasts where there is no protective facility such as seawalls. In some cases we can find out run-up height by field surveys of evidence after the tsunami events.

"Tsunami inundation depth" means the water depth on land. It is used in tsunami hazard maps, which show expected inundation areas with water depth there.

"Wave height" is the difference from peak to trough of the wave, and it is used in measuring wind waves.



Earthquake Monitoring System in and around Tokai region

Various kinds of instruments such as seismometers, strainmeters and GPS are installed in and around the Tokai region. (See the figure below.) These observational data are continuously transmitted to the JMA Headquarters.

These observations are maintained under joint cooperation effort with the Geographical Survey Institute, Japan Coast Guard, the University of Tokyo, Nagoya University, National Research Institute for Earth-Science and Disaster Prevention, Advanced Industrial Science And Technology, Shizuoka Prefecture and others.

What is the strainmeter?

The strainmeter has an important role to detect the Pre-slip (See Page 7) prior to the Tokai Earthquake.

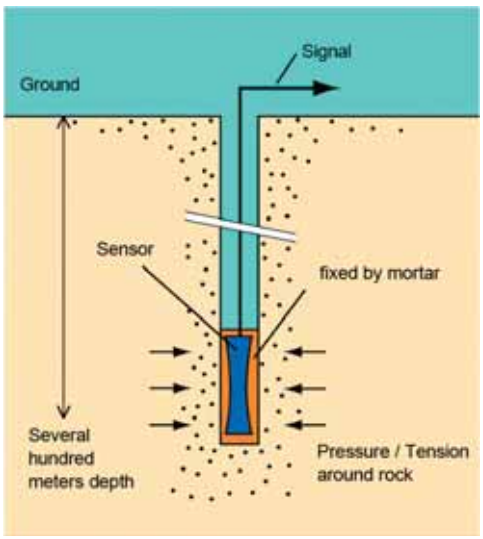
The strainmeter measures very minute expansion or contraction of underground rock. Its cylindrical sensor is settled at the bottom of borehole whose diameter is about 15cm and depth is several hundred meters. The sensor detects its deformation by pressure or tension surrounding rocks with very high precision.

The strainmeter can measure one billionth of relative change of crustal expansion or contraction.

JMA uses two types of strainmeter. One is Volume Strainmeter, which measures amount of expansion or contraction of volume, and the other is Multi Components Linear Strainmeter, which measures not only amount but also direction of expansion or contraction of surrounding rock.

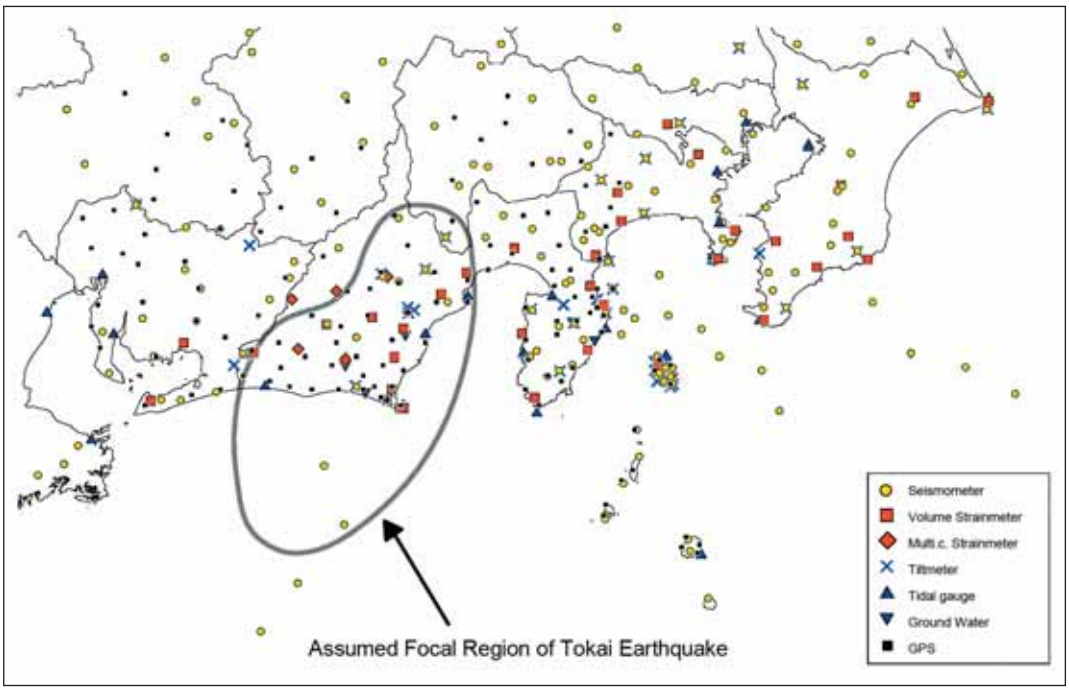
The data observed by these strainmeters are used for information about Tokai Earthquake.

■ Mechanism of Strainmeter



Strainmeter is an instrument to detect the condition of surrounding rock by measuring precise deformation of the sensor.

■ Observation Network for Prediction of Tokai Earthquake



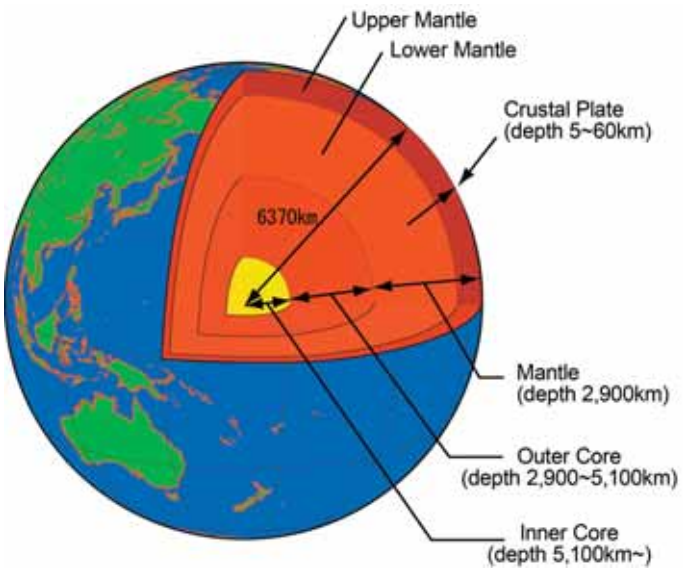
Basic Knowledge on Earthquake and Tsunami

Structure of the Earth

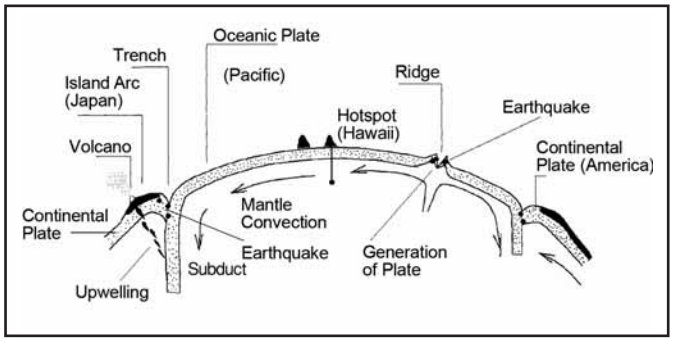
The earth consists of crust, mantle and core. The crust and mantle are solid but in the long term perspective, they flow slowly.

In the earth's interior, the temperature rises higher as getting closer to the center of the sphere and convection are taking place. Plates (composed of crust and upper mantle) are produced on surface of the earth where internal mass is upwelling. The plates diverge and drift on the surface very slowly, a few centimeters per year. At the end, the plates subduct into the mantle and disappear. The earth is covered by such ten and several plates.

■ Structure of the Earth's Interior



■ Crustal Movement



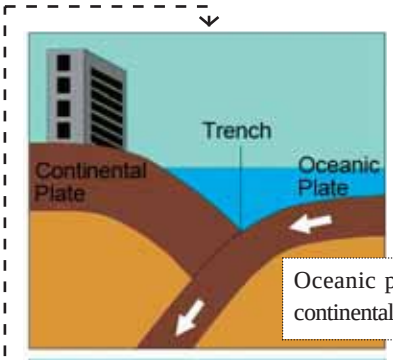
Mechanism of Earthquake

Each plate on the earth's surface drifts to different directions. Therefore, at the plate boundaries, they are pushing or rubbing each other or subducting beneath another.

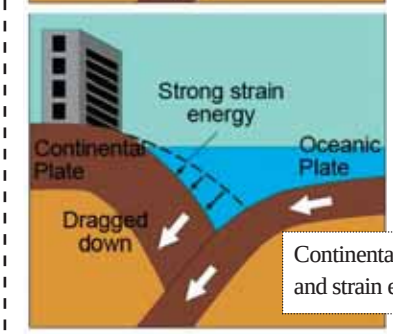
Around Japan, the oceanic plates are subducting beneath the continental plates and large earthquakes often occur. In addition, the strain energy is stored in the continental plates and this is supposed to cause shallow earthquakes in land areas.

■ Large Earthquakes around Trench

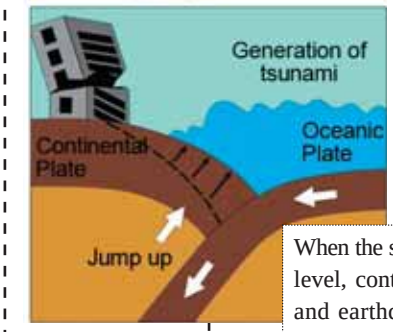
(source: Headquarters for Earthquake Research Promotion)



Oceanic plate subducts beneath continental plate.



Continental plate is dragged down and strain energy is stored.



When the strain exceeds the certain level, continental plate jumps up and earthquake and tsunami are generated.

return to the beginning

Seismic Activity in the World

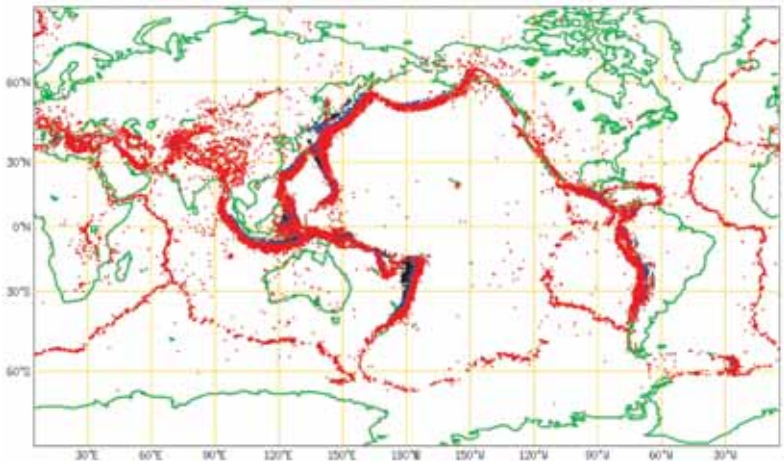
Most of the earthquakes occur along the plate boundaries where crustal plates are produced (ridge or rift valley), subducting beneath others (trench) or rubbing against each other. Around the trenches the Chilean Earthquake occurred in 1960, which is the largest in the 20th century, and the off Sumatra Island Earthquake occured in 2004, which caused the unprecedented Indian Ocean wide tsunami disasters.

Seismic Activity in Japan

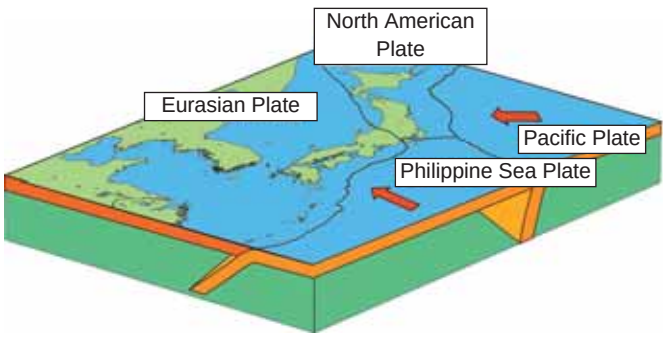
Since Japan is located on the plate boundary where two oceanic plates (Pacific Plate and Philippine Plate) are subducting beneath two continental plates (Eurasian Plate and North American Plate), Japan is one of the most earthquake-prone countries in the world. Earthquakes occur not only around the plate boundary but also in the plates. When an earthquake takes place directly below a city, it may causes serious damage.

Among the earthquakes around the plate boundaries are the Tokai Earthquake and the Tonankai/Nankai Earthquake (along the trench from off Tokai to off Shikoku), and the off Miyagi Prefecture Earthquake and the off Tokachi Earthquake (around the Japan Trench and the Chishima Trench). The South Hyogo prefecture Earthquake in 1995 and the Mid Niigata Prefecture Earthquake in 2004 occurred in land areas.

■ Distribution of Earthquakes in the World (M4.0 or greater in 1995-2004, USGS)

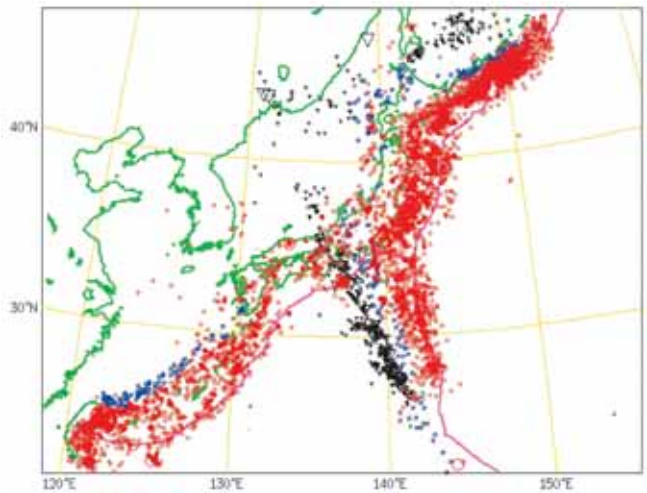


■ Crustal Plates around Japan



Around Japan, the Pacific Plate and the Philippine Sea Plate are subducting beneath the continental plates (Eurasian Plate and North American Plate) from east and south, respectively and earthquakes often occur along the boundaries.

■ Earthquakes around Japan (M4.0 or greater in 1995-2004, JMA)



Tsunami

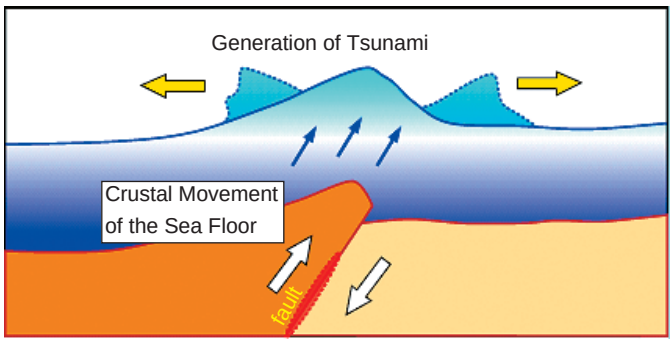
When a large earthquake occurs in ocean area, the sea floor rises up or sinks down. Accordingly, the water on the sea floor also move up or down massively and this movement spreads out in all directions in the ocean. This phenomenon is tsunami. Tsunami can be also generated by uplift of ocean bottom caused by submarine volcanic activity or by landmass slipping into the sea caused by a volcanic eruption.

Tsunami is so long-period waves that it propagates for long distance without being attenuated.

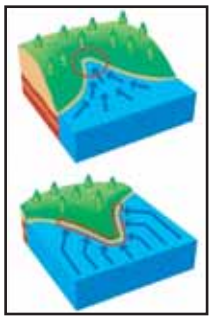
Tsunami waves become slower as the sea becomes shallower (however still faster than humans run). Therefore, the following waves catch up ahead near the coast and the tsunami grows drastically higher. Depending on the geographical condition, tsunami waves are reflected and diffracted and in some areas under the specific conditions tsunami grows much higher.

Some tsunamis run up far into the land. Tsunami is a movement of the whole of sea water from the surface to the bottom, and maintains huge energy so that it destroys buildings and washes ships away and rocks on land. The washed-out ships clash against buildings and destroy them. Tsunami sometimes runs up on rivers and causes damages to the riverside areas.

■ Mechanism of Tsunami Generation

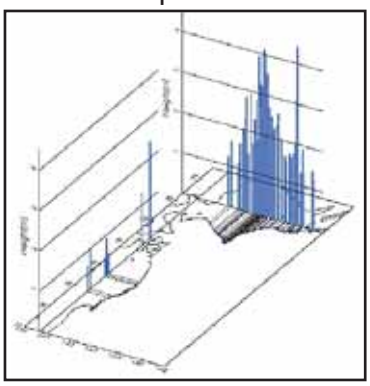


■ Geographical Effect

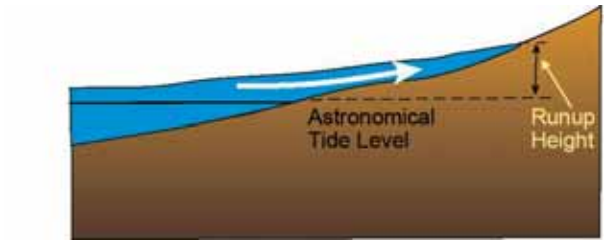


Tsunami concentrates to red-outlined areas.

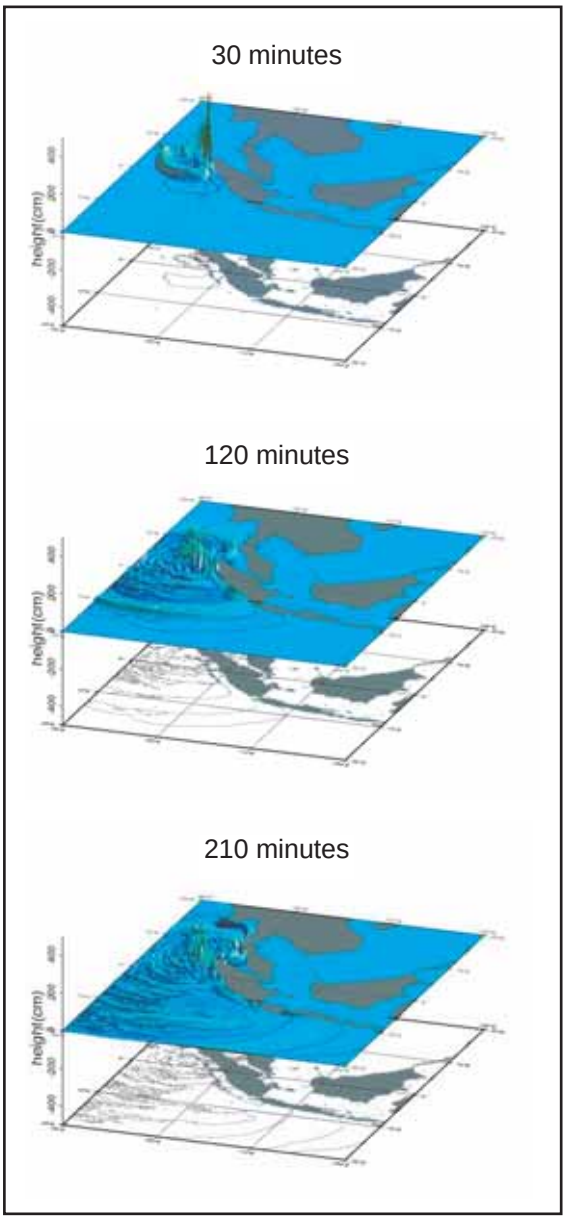
■ Tsunami Height for the off Tokachi Earthquake in 2003



■ Tsunami Runup



■ Simulation on the Indian Ocean Tsunami on December 26 2004



Can Earthquakes be Predicted?

If earthquakes were able to be predicted, we could reduce damages caused by the earthquakes.

Currently, it is extremely difficult to predict occurrence of earthquakes except Tokai Earthquake even though considerable progresses have been achieved in research on earthquakes recently. Earthquake prediction means to predict when, where and how large earthquake will occur in advance based on scientific grounds. From ancient days, some phenomena are reported as the possible precursors of the earthquakes after large earthquakes. But there are only a few which could have been the precursors from the scientific point of view. There remains no way to predict when, where and how large earthquake will occur precisely. Earthquake prediction is still on a research stage, not operational.

However, Tokai Earthquake is the only one which is expected to be predicted. As for Tokai Earthquake, the pre-slip phenomenon is considered to happen just before the Earthquake. What JMA is trying for prediction of Tokai Earthquake is to detect the pre-slip and if the pre-slip actually takes place and is successfully detected, JMA issues information about Tokai Earthquake. However, there is a possibility the pre-slip could take place too slightly to be detected by sensors. Therefore, it can not be said that the Tokai Earthquake will be able to be predicted definitely.

Preparation for Earthquakes

Earthquakes destroy buildings and then the collapsed buildings crush people to death. If the earthquake generates tsunami, the tsunami also destroys buildings and kills people. Sometimes the earthquakes cause liquefaction on the soft ground and the buildings incline.

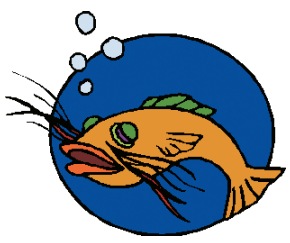
Large earthquakes have been occurring repeatedly around the trenches near Japan. In addition, there are more than 2,000 active faults in Japan and great earthquakes possibly occur there in near future. Moreover, some earthquakes smaller than M7.0 occur elsewhere with no fault traces on surface, like the Mid Niigata Prefecture Earthquake in 2004. Such unexpected earthquakes may occur anywhere in Japan.

As mentioned above, Japan is always at risk for destructive earthquakes, which can not be predicted beforehand. We should keep ourselves to be prepared for earthquakes by reinforcement of buildings and fixing furniture against strong motion and by checking and being aware of refuge zones and evacuation routes as for tsunami caused by the earthquakes.

Column: Precursor of Earthquake!?

Sometimes it is reported that some kinds of phenomena were observed a few days before the earthquake occurrence. But currently such phenomena are not officially referred for earthquake prediction.

There are about 2,000 earthquakes per year in Japan which people can feel (seismic intensity scale 1 or greater). On an average, 5 earthquakes occur somewhere per day. Earthquakes of seismic intensity 4 or greater, which many people feel frightened, occurred 90 times in 2004. Earthquakes happen on a daily basis in Japan. Therefore, if a phenomenon happens, even if it is not related to earthquake occurrence, some time later an earthquake occurs somewhere in Japan. If such chances take place repeatedly, it seems to be some linkage between the two events. But without the verification of the theory, it is not accepted as the precursor of large earthquakes just by listing the chances.



Tokai Earthquake

Tokai Earthquake is assumed to occur in near future along the trench near Suruga Bay, supposed to be as large as M8-class earthquake.

Large earthquakes of M8-class have occurred every 100-150 years in the area from the Suruga Trough (=ocean trench) in Suruga Bay to the trough off Shikoku Island. These earthquakes are called Tonankai Earthquakes and Nankai Earthquakes. But when the last Tonankai Earthquake (1944, M7.9) and the Nankai Earthquake (1946, M8.0) occurred, the crust along the Suruga Trough did not move. Because the Suruga Trough (E-region in figure below) has been unmoved for 150 years, the Tokai Earthquake is supposed to occur in near future.

We maintain dense observation network for Tokai Earthquake, because its assumed focal region is partly lay on the ground area and it is supposed to detect precursory phenomena in high probability. (See P19.)

Tonankai, Nankai Earthquake

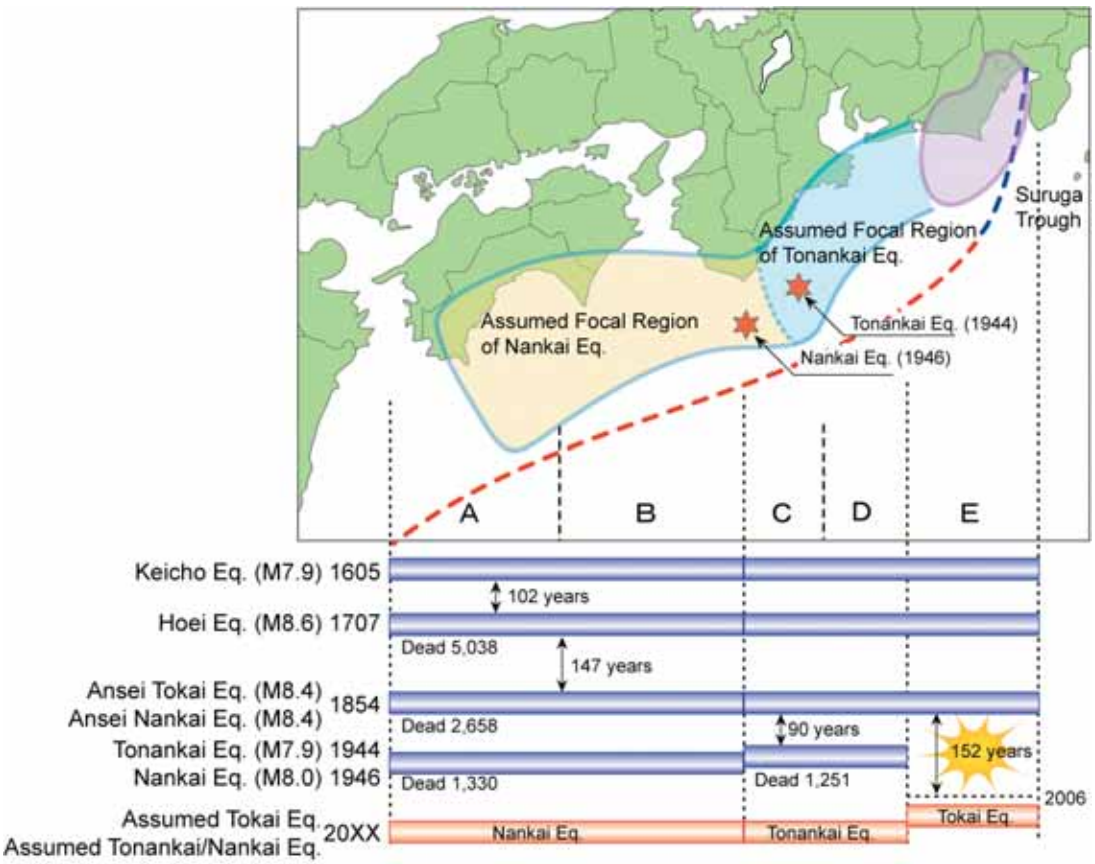
In the area from Western Enshunada to off Shikoku Island, west of the assumed focal region of Tokai Earthquake, large earthquakes of M8-class such as the Ansei-Tokai Earthquake (1854) and the Ansei-Nankai Earthquake (1854), the Showa-Tonankai Earthquake (1944) and the Showa-Nankai Earthquake (1946) have occurred.

Because of the interval time of 100-150 years and lapsed time from the last large earthquakes in this area, large earthquakes are supposed to occur again in the first half of this century. These are Assumed Tonankai and Nankai Earthquake.

According to historical records, in this area it happened that two large earthquakes occurred in the same time or with the time of interval about 32 hours.

If these earthquakes occur, strong ground motion and tsunami will probably occur and cause severe damage in the wide area from Tokai Area to Kyushu Island.

■ Large Earthquakes occurred in the area from Suruga Bay to off Shikoku Island



Focal regions of ocean-trench earthquakes after 1600 are shown in every A-E area by time order. Large earthquakes occurred with the almost same time of interval in every area with 100-150 years.

Histrical Record on Major Earthquakes in Japan

Date	Magnitude	Epicenter Region / Earthquake Name	Lives Lost(L)/Missing(M)	Tsunami
14 Mar 1872	7.1	Ishimi, Izumo（Hamada Earthquake）	L: 555	○
28 Oct 1891	8.0	W of Gifu Pref.（Nobi Earthquake）	L: 7,273	
22 Oct 1894	7.0	Syonai Plain（Syonai Earthquake）	L: 726	
15 Jun 1896	8.5	Far off Sanriku（Meiji Sanriku Tsunami Earthquake）	L: 21,959	○
31 Aug 1896	7.2	Boundary of Akita and Iwate Pref.（Rikuu Earthquake）	L: 209	
1 Sep 1923	7.9	S of Kanto District（Sagami Bay）（Kanto Earthquake）	L: 99,331 M: 43,476	○
23 May 1925	6.8	N of Hyogo Pref.（Northern Tajima Earthquake）	L: 428	
7 Mar 1927	7.3	N of Kyoto Pref.（Northern Tango Earthquake）	L: 2,925	○
26 Nov 1930	7.3	E of Shizuoka Pref.（Northern Izu Earthquake）	L: 272	
3 Mar 1933	8.1	Far off Sanriku（Syowa Sanriku Earthquake）	L: 1,522 M: 1,542	○
10 Sep 1943	7.2	E of Tottori Pref.（Tottori Earthquake）	L: 1,083	
7 Dec 1944	7.9	Sea off Kii Peninsula（Tonankai Earthquake）	L & M: 998	○
13 Jan 1945	6.8	Mikawa Bay（Mikawa Earthquake）	L: 1,961	○
21 Dec 1946	8.0	Sea off Kii Peninsula（Nankai Earthquake）	L: 1,330 M: 113	○
28 Jun 1948	7.1	Reihoku region of Fukui Pref.（Fukui Earthquake）	L: 3,769	
4 Mar 1952	8.2	Sea off Tokachi（Sea off Kushiro）（The Sea off Tokachi Earthquake in 1952）	L: 28 M: 5	○
23 May 1960	9.5	The Coast of Chile「Chile Tsunami Earthquake」	L: 122 M: 20	○
19 Aug 1961	7.0	Kaga region of Ishikawa Pref.「Northern Mino Earthquake」	L: 8	
30 Apr 1962	6.5	N of Miyagi Pref.「Northern Miyagi Pref. Earthquake」	L: 3	
27 Mar 1963	6.9	Sea off Fukui Pref.「Sea off Echizen Cape Earthquake」	(none)	
16 Jun 1964	7.5	Sea off Niigata Pref.「Niigata Earthquake」	L: 26	○
from 3 Aug 1965 to the end of 1970	5.4	N of Nagano Pref.「Matsushiro Earthquake Swarm」	(none)	
21 Feb 1968	6.1	Boundary of Kagoshima and Miyazaki Pref.「Ebino Earthquake」	L: 3	
1 Apr 1968	7.5	The Sea of Hyuga「The Sea of Hyuga Earthquake in 1968」	(none)	○
16 May 1968	7.9	Sea off Tokachi「The Sea off Tokachi Earthquake in 1968」	L: 52	○
4 Dec 1972	7.2	E of Hachijyojima Isaland「The East off Hachijyojima Island Earthquake on 1972.12.4」	(none)	○
17 Jun 1973	7.4	Sea off Nemuro Peninsula「The Sea off Nemuro Peninsula Earthquake in 1973」	(none)	○
9 May 1974	6.9	Sea off Izu Peninsula「The Sea off Izu Peninsula Earthquake in 1974」	L: 30	○
14 Jan 1978	7.0	Sea near Izuoshima Island「The Sea near Izuoshima Island Earthquake in 1978」	L: 25	○
12 Jun 1978	7.4	Sea off Miyagi Pref.「The Sea off Miyagi Pref. Earthquake in 1978」	L: 28	○
21 Mar 1982	7.1	Sea off Urakawa「The Sea off Urakawa Earthquake in 1982」	(none)	○
26 May 1983	7.7	Sea off Akita and Aomori Pref.「The Center of the Sea of Japan Earthquake in 1983」	L: 104	○
14 Sep 1984	6.8	W of Nagano Pref.「The Western Nagano Pref. Earthquake in 1984」	L: 29	
15 Jan 1993	7.5	Sea off Kushiro「The Sea off Kushiro Earthquake in 1993」	L: 2	
12 Jul 1993	7.8	SW off Hokkaido「The Southwest off Hokkaido Earthquake in 1993」	L: 201 M: 28	○
4 Oct 1994	8.2	E off Hokkaido「The East off Hokkaido Earthquake in 1994」	(none)	○
28 Dec 1994	7.6	Far off Sanriku「The Far off Sanriku Earthquake in 1994」	L: 3	○
17 Jan 1995	7.3	Awajishima Island（The Akashi Straits）「The Southern Hyogo Prefecture Earthquake in 1995」	L: 6,434 M: 3	○
6 Oct 2000	7.3	E of Shimane Pref.（Boundary of Shimane and TottoriPref.）「The Western Tottori Prefecture Earthquake in 2000」	(none)	
24 Mar 2001	6.7	The Sea of Aki「The Geiyo Earthquake in 2001」	L: 2	
26 Sep 2003	8.0	Sea off Tokachi「The Tokachi-oki Earthquake in 2003」	L: 1 M: 1	○
23 Oct 2004	6.8	Chuetsu Region of Niigata Pref.「The Mid Niigata prefecture Earthquake in 2004」	L: 59	

Note 1: In the column of Epicenter Region / Earthquake Name, the names in 「」 are named by JMA. Those in ( ), which had occurred before JMA started naming major earthquakes, are the names used generally.
Note 2: Magnitude of Chile Earthquake is in moment magnitude determined by USGS, and that of Matsushiro earthquake swarm is the most largest earthquake's.
Note 3: The number of L and M is based on 'All about major earthquakes which caused damages -the newest edition' by Tatsuo Usami, 'A chronological table of science -the 2006 edition' by National Astronomical Observatory of Japan, a report by Moroi and Takemura (2002), and the report by Fire and Disaster Management Agency
Note 4: The open circle shows that the tsunami was observed.

Knowledge on Earthquake

1. Hide yourself under a table or a desk and do not go out in a hurry.
2. No strong shake goes on more than 1 minute.
3. Acquire information on the earthquake on the television or the radio.
4. Leave immediately to highland when a strong shake has been felt on the seashore.
5. Keep away from vender machines and buildings.
6. Be careful of landslide.
7. Evacuate on foot with minimum belongings.
8. Do not be in a panic and take actions based on correct information on occurrence of aftershocks.
9. Prepare for unexpected earthquake disasters.

Knowledge on Tsunami

1. Leave the seashore immediately and take shelter to the place of safety, when a strong shake (seismic intensity※ 4 or greater) or a weak but long time slow shake has been felt.
2. Leave the seashore immediately and take shelter to the place of safety, when a tsunami warning has been issued.
3. Acquire correct information on the television, the radio, and via the internet, etc.
4. Do not go to the seashore for bathing or fishing when a tsunami advisory or a tsunami warning is issued.
5. Do not feel relieved until the warning is cleared because tsunami may attack repeatedly.

※JMA scale

Japan Meteorological Agency

Website: http://www.jma.go.jp