If you feel a tremor

Remain calm, and secure your personal safety !

If you see/hear an EEW

At Home

- Protect your head and shelter under a table
- Don't rush outside
- Don't worry about turning off the gas in the kitchen

When Driving

- Don't slow down suddenly
- Turn on your hazard lights to alert other drivers, then slow down smoothly
- If you are still moving when you feel the earthquake, pull safely over to the left and stop

In PublicBuildings

- Follow the attendant's instructions
- Don't rush to the exit

Outdoors

- Look out for collapsing concrete-block walls
- Be careful of falling signs and broken glass

On Buses or Trains

- Hold on tight to a strap or a handrail

In Elevators

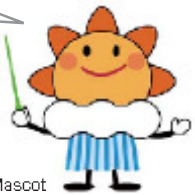
- Stop the elevator at the nearest floor and get off immediately

Tips to protect yourself from tsunamis

- Leave coastal areas immediately and evacuate to a safe place if strong shaking (seismic intensity of 4 or greater) or weak but long-lasting slow shaking is felt.
- Even if you do not feel shaking, leave coastal areas immediately and evacuate to a safe place if a Tsunami Warning is issued.
- Use TV, radio and/or the Internet to obtain accurate information.
- Do not go to the seashore to engage in bathing or fishing activities when a Tsunami Advisory or Tsunami Warning is in effect.
- Remain on alert until the warning is cancelled, as tsunamis may strike repeatedly.

JMA Website

For more information and facts about meteorology, earthquakes and volcanoes, visit JMA's website at http://www.jma.go.jp/jma/indexe.html



Harerun the JMA Mascot

Japan Meteorological Agency
1-3-4 Otemachi, Chiyoda-ku, Tokyo 100-8122,Japan
Phone: +81-3-3212-8341
Website: http://www.jma.go.jp/jma/indexe.html

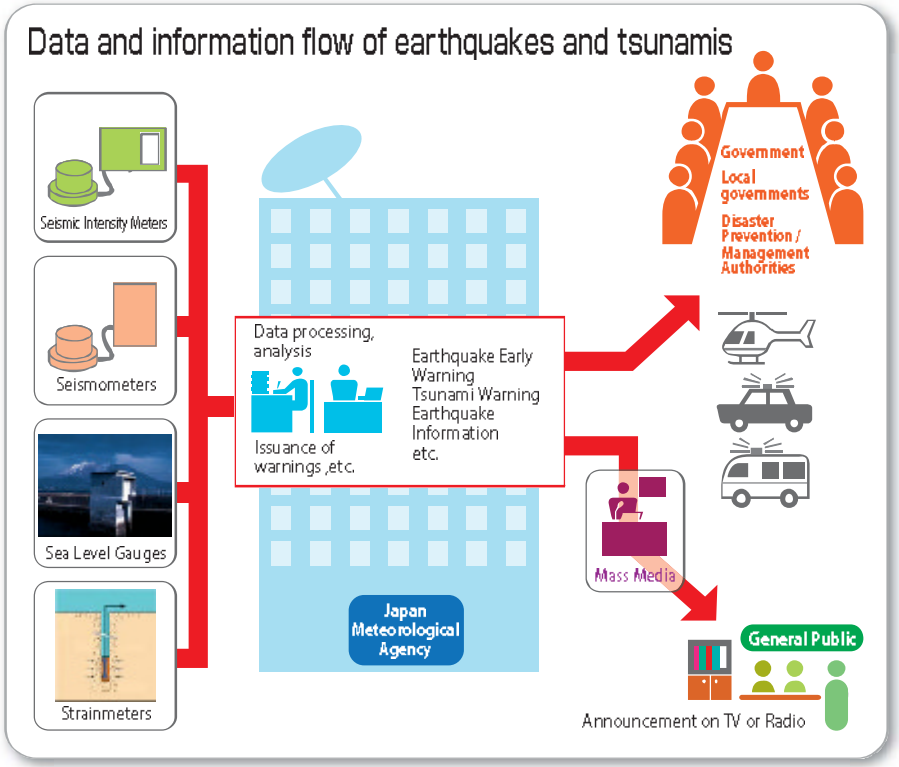
March 2009

Earthquakes and Tsunamis

～Disaster prevention～

Japan Meteorological Agency

Contents



1 Preface
- How to Use Warnings and Information for Disaster Prevention -

Japan is one of the most earthquake-prone countries in the world, and has repeatedly suffered serious damage caused by earthquakes and tsunamis.


▲The Mid Niigata prefecture Earthquake in 2004


▲The Iwate-Miyagi Nairiku Earthquake in 2008

What would happen if there were no earthquake/tsunami information when a tremor hits? The absence of information on areas that are at risk of tsunami strikes or subject to strong shaking would delay evacuation and emergency response by disaster prevention agencies, and may result in extensive damage.

The Japan Meteorological Agency (JMA) promptly issues warnings and information on earthquakes and tsunamis to mitigate disasters and protect life and property.

Examples:

- In the event of large earthquakes, JMA announces earthquake alerts before strong tremors arrive **(Earthquake Early Warnings)**.
- In the event of large earthquakes in ocean areas, JMA announces estimated tsunami heights and their arrival times in advance **(Tsunami Warnings/Advisories)**.
- In the event of earthquakes, JMA announces hypocenter, magnitude and where strong shaking has been felt **(Earthquake Information)**.

To utilize above information, it is very important to understand the announcements made by JMA and to have a certain level of awareness in regard to earthquakes and tsunamis.

This brochure explains various types of information and warnings and outlines JMA's monitoring network. Basic facts about earthquakes and tsunamis are also included.

This resource aims to help people understand the various types of information issued by JMA to prevent and mitigate disasters caused by earthquakes and tsunamis.

Earthquake & Tsunami Warnings/Information in JAPAN

Example : 2008/09/11 Tokachi-oki (M7.1)

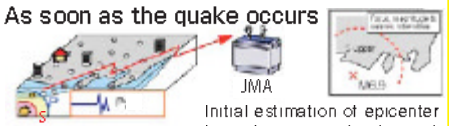
Earthquake Early Warning ➡P.04

Origin Time : 09:20:51

Earthquake!

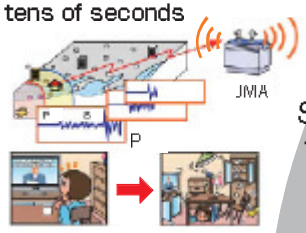
Fastest Detection: 09:21:03

As soon as the quake occurs



Initial estimation of epicenter location, magnitude and seismic intensity using data.

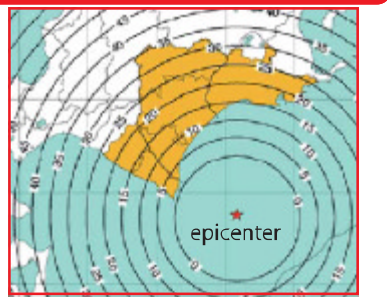
After several seconds to a few tens of seconds



Earthquake Early Warning is issued to the general public.

Several to a few tens of seconds

Earthquake Early Warning 09:21:13



Warning area

The contours represent the lead time (in seconds) from the Earthquake Early Warning to the arrival of strong motion.

Principle See p.20

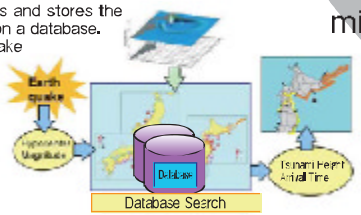
Tsunami Warnings/ Advisories ➡P.05

JMA issues a Tsunami Warning as soon as an earthquake hits.

- JMA monitors earthquakes and tsunamis around the clock.
- Prior computer simulation of tsunamis has been conducted with earthquake scenarios involving various locations and magnitudes, and the resulting information on estimated tsunami arrival times and heights is stored on a database.
- Tsunami Warnings are issued using the closest-matching results from the database.

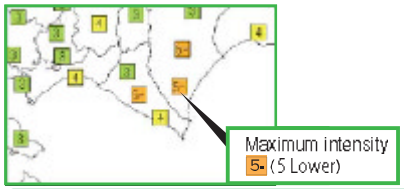
Tsunami Forecasts

JMA conducts prior computer simulation of tsunamis and stores the results on a database.



2-3 minutes

Tsunami Warning

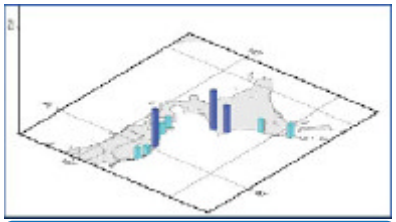


Seismic Intensity Information (regions with seismic intensity of 3 or greater) : 09:22

Earthquake Information (location and magnitude)

Tsunami Warning 09:24

Tsunami Information (estimated tsunami heights and arrival times) : 09:24

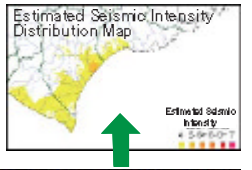


Tsunami Information (observed tsunami heights and arrival times)

- Major Tsunami
- Tsunami
- Tsunami Advisory

About 5 minutes

Tsunami Warning (cancellation) 10:45

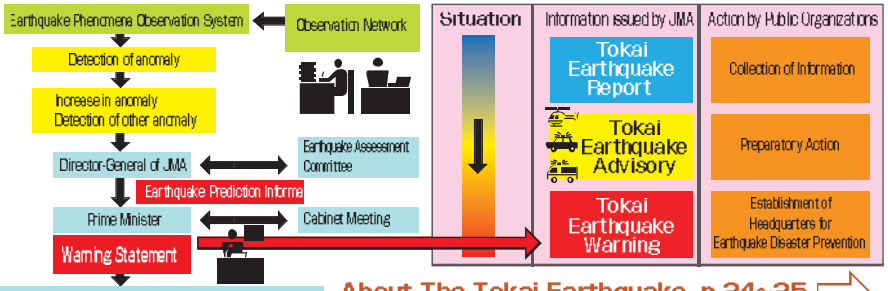


Information on Seismic Intensity at each site (stations observing an intensity of 1 or greater) : 09:26

Earthquake and Seismic Intensity Information (location/magnitude and regions with seismic intensity of 3 or greater) : 09:26

Earthquake Information ➡P.06

Information on the Tokai Earthquake ➡P.08



About The Tokai Earthquake p.24~25

Forecast method p.21

2 Earthquake and Tsunami Warnings

When JMA anticipates damage from an earthquake, it issues warnings and forecasts using observed data.

JMA has two kinds of warnings on earthquakes: one is an Earthquake Early Warning, which predicts strong motion, and the other is a Tsunami Warning, which predicts tsunamis. The Agency also issues public advisories and forecasts if the expected level of damage is below the criteria for these warnings to be issued.

Earthquake Early Warnings

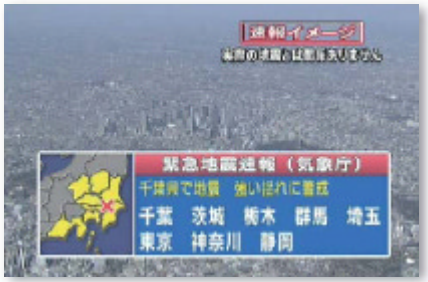
Earthquake Early Warnings (EEWs) are warnings (or forecasts) of strong motion to be issued several seconds to several tens of seconds before its arrival.

If the estimated seismic intensity is above 5-lower, an EEW is issued to areas where the estimated seismic intensity is 4 or greater through media such as TV and radio.

The main benefit of EEW is that they are issued before the arrival of strong shaking. Strong tremors caused by earthquakes strike suddenly. However, notice of their arrival several seconds to several tens of seconds in advance allows people to take action to protect themselves, such as promptly moving away from windows and shelves or taking cover under a sturdy table. As there are only a few moments before strong tremors arrive, after the issuance of EEW there may be no time to consider how to react on hearing EEW; this makes it important to carry out emergency response drills so that appropriate action can be taken as soon as a warning is given. In areas close to the focus of the earthquake, however, an EEW may not be transmitted before the tremors hit and errors of ±1 or so may be included in the estimated seismic intencity of EEW.

It should be noted that there are such limits to the accuracy of EEW.

◆ Example of an EEW broadcast image (NHK)



◆ EEW

Criterion	Contents	Examples of responses to EEW
Predicted seismic intensity is 5-lower or greater.	Names of areas where seismic intensity is predicted to be 4 or greater	Provided through various media (e.g., TV and radio) to the general public.

Tsunami Warnings/Advisories and Tsunami Information

Tsunamis are one of damaging phenomena caused by earthquakes. If a tsunami strikes a coastal area, it can cause death or serious injury to people and damage to buildings.

When an earthquake occurs, JMA estimates whether a tsunami has been generated. If a disastrous tsunami is expected in coastal regions, JMA issues a Tsunami Warning/Advisory for each region (66 individual regions are defined to cover all coastal areas of the country).

Tsunami Warnings/Advisories are categorized into three levels – Tsunami Warning (Major Tsunami), Tsunami Warning (Tsunami) and Tsunami Advisory – according to the estimated tsunami height. JMA also issues information on tsunami details such as estimated arrival time and height. If no damage is expected, a Tsunami Forecast is issued.

Warnings/Advisories may be changed or updated based on observed tsunami heights.

◆ Tsunami Warnings/Advisories

Category		Indication	Action to be taken
Tsunami Warning	Major Tsunami	Tsunami height is expected to be 3 meters or more.	Leave coastal areas immediately and evacuate to a safe place.
	Tsunami	Tsunami height is expected to be up to 2 meters.	
Tsunami Advisory		Tsunami height is expected to be about 0.5 meters.	Leave coastal areas and do not engage in fishing or swimming activities.

◆ Tsunami Forecast

Forecast of changes in sea level	Indication
No tsunami is expected	A "No tsunami is expected" message is added to the Earthquake Information.
Expected height of sea level change less than 0.2 m.	No damage is expected as changes in sea level will be less than 0.2 m.
Slight sea level changes may still occur after Tsunami Advisory cancellation.	Pay attention when engaging in fishing, swimming or other activities, as changes in sea level may still occur for the time being.

◆ Tsunami Information

Tsunami-related messages	Indication
Tsunami Information (forecast of height and arrival time of initial wave)	Forecasts of the height and arrival time of the initial wave are provided for each forecast region.
Tsunami Information (arrival time of tsunami and high tide)	Information on the estimated time of high tide and forecasts of tsunami arrival times at several points are provided.
Tsunami Information (tsunami observations)	Arrival times and tsunami heights observed at tsunami observation stations are provided.

◆ Tsunami Forecast Regions

3 Earthquake Information

JMA issues predictive information such as Tsunami Warnings/Advisories and Earthquake Early Warnings as well as earthquake information based on the results of observations.

◆ Earthquake Information issued by the JMA

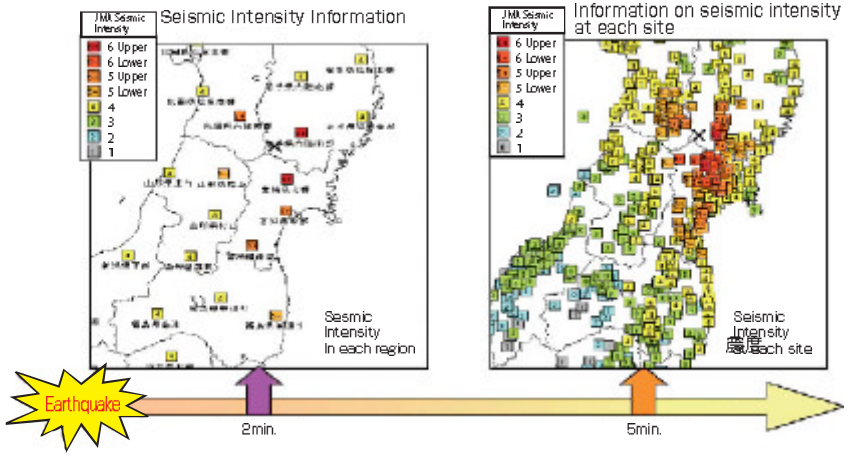
Title	Content and timing of issue
Seismic Intensity Information	Occurrence of an earthquake Regions with seismic intensity of 3 or greater (Issued within two minutes of earthquake occurrence)
Earthquake Information	Earthquake hypocenter and magnitude Remark - either "No threat of tsunami" or "Sea levels may change slightly, but no danger is expected." (Issued when no tsunami forecast is announced.)
Earthquake and Seismic Intensity Information	Earthquake hypocenter and magnitude Cities/towns/villages with seismic intensity of 3 or greater, and those with estimated seismic intensity of 5-lower or greater with no reports from seismic intensity meters
Information on seismic intensity at each site	Earthquake hypocenter and magnitude Sites with seismic intensity of 1 or greater
Information on the number of earthquakes	Number of earthquakes with seismic intensity of 1 or greater (Issued if earthquakes occur repeatedly.)
Shake Map(Estimated Seismic Intensity Distribution Map)	Estimated Seismic Intensity Distribution Map based on seismic intensity data (Issued when seismic intensity is 5-lower or greater.)

Seismic Intensity Information and Information on seismic intensity at each site

When seismic intensity is 3 or greater, JMA issues Seismic Intensity Information within two minutes to allow emergency action to be taken.

The seismic intensities are disseminated to disaster management organizations and are used as a trigger for their emergency operation. They are also broadcast to the public by TV, radio and other media. For example, the Cabinet Secretariat will call a meeting of the designated emergency response team in the event of a quake with seismic intensity of 6-lower or greater.

◆ Issuance of Seismic Intensity Information and Information on Seismic Intensity at each site
(The Iwate-Miyagi Nairiku Earthquake in 2008)

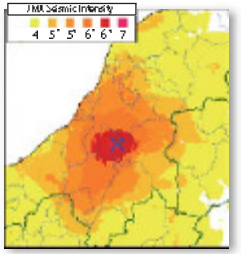


Shake Map(Estimated Seismic Intensity Distribution Map

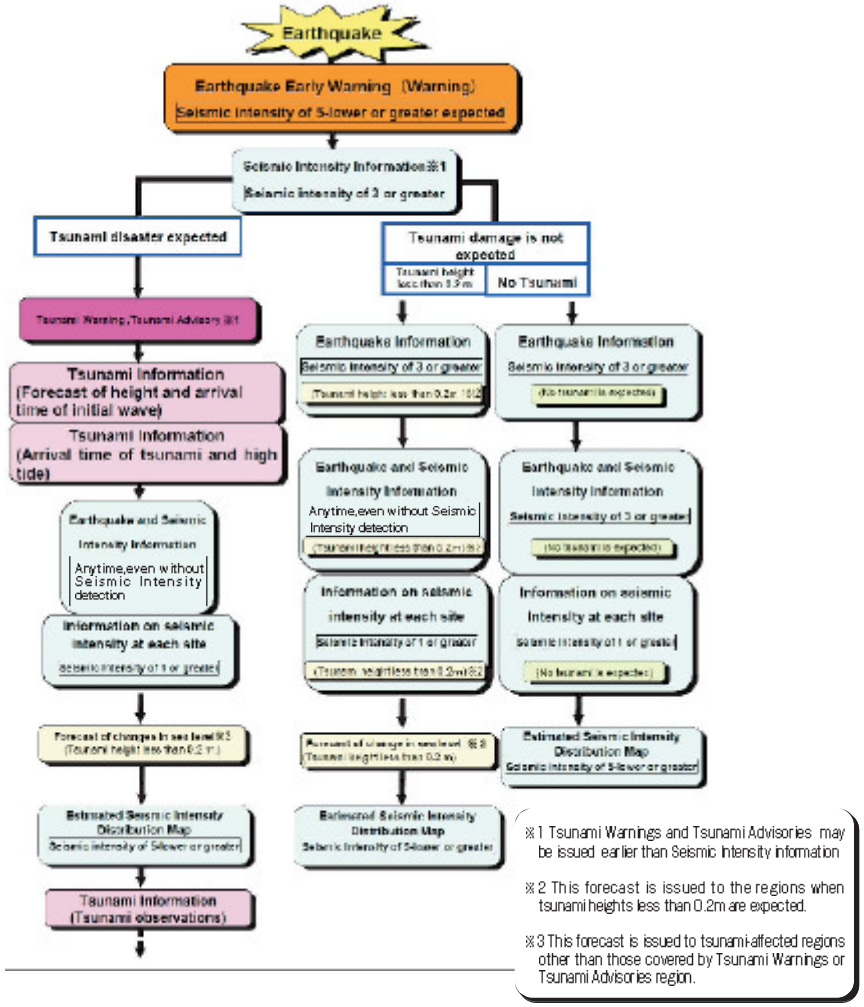
To enable prompt emergency measures to be taken by disaster management authorities, JMA analyzes seismic intensity taking into account the surface geology for each grid space, and draws an Estimated Seismic Intensity Distribution Map that shows estimated seismic intensity in places without seismic intensity meters.

As the analyzed values have a margin of error, users should focus on the extent and distribution of strong ground motion areas rather than the respective estimated value for each grid.

◆ Estimated Seismic Intensity Distribution Map
(The Mid Niigata prefecture Earthquake in 2004)



Flow of issuance of information on tsunamis and earthquakes



4 Tokai Earthquake Prediction and Information

Information about Tokai Earthquake

In Japan, a large-scale earthquake with a magnitude of around 8 (referred to as the Tokai Earthquake) is widely expected to hit the Tokai region in the near future. In order to predict the occurrence of the Tokai earthquake, JMA has developed a seismic and crustal deformation observation network throughout the region in conjunction with related organizations, and observes data coming from them on around-the-clock basis (see p.16). If anomalous data are detected, JMA issues Information on the Tokai Earthquake bulletins to allow preparatory action and emergency measures for earthquake disaster prevention. These are categorized into three types: **Tokai Earthquake Report**, **Tokai Earthquake Advisory**, and **Tokai Earthquake Warning**.

Sample of "Information about Tokai Earthquake" on the JMA web site

"Tokai Earthquake Report" is currently issued.
Keep watching TV or listening to the radio for more information. Attention should be given to information from TV/Radio. No further action is required.

"Tokai Earthquake Advisory" is currently issued.
Attention should be given to information from TV/Radio. Act on the notice from the government and the disaster management plan by the local governments.

"Tokai Earthquake Warning" is currently issued.
Attention should be given to information from TV/Radio. Act on the warning statements from Prime Minister and the disaster management plans of local governments.

Earthquake Assessment Committee for Areas under Intensified Measures against Earthquake Disaster

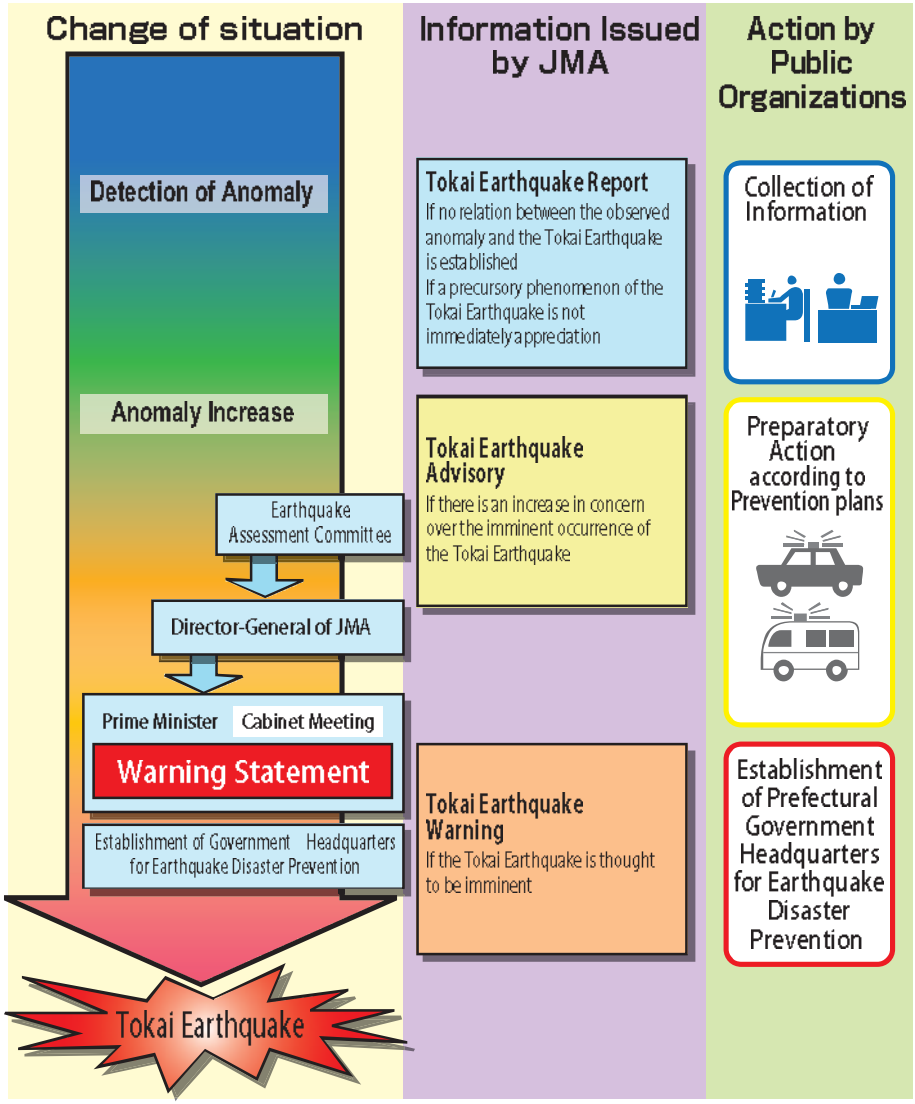
◆ **Earthquake Assessment Committee for Areas under Intensified Measures against Earthquake Disaster**
(monthly meeting)

If any anomalous phenomena observed are considered to be precursors of the Tokai Earthquake, JMA will convene the Earthquake Assessment Committee for Areas under Intensified Measures against Earthquake Disaster, which consists of earthquake seismologist.

If the Committee concludes that the Tokai Earthquake is imminent, the Director-General of JMA will report this conclusion to the Prime Minister, who will then hold a Cabinet meeting and issue a warning statement.

Flow of Information about Tokai Earthquake

~ from Detection of Anomaly to Warning Statement ~



5 Information on Large Earthquakes and Tsunamis

Prompt Report of Occurrence of a Large Earthquake (News Release)

When a large earthquake occurs, JMA issues a Prompt Report of Occurrence of a Large Earthquake and Tsunami (hypocenter, magnitude, possibility of tsunami, areas of strong motion, historical earthquake activity around the hypocenter). If there is possibly serious damage, the Agency announces information on the earthquake and issues important notices to the public through the news media (News Release).

Press conference

<Prompt Report about a Large Earthquake>
- Hypocenter and magnitude
- Possibility of tsunami
- Areas of strong motion
- Historical earthquake activity

<News Release>
(when there is possibly serious damages)
In addition to the prompt report,
- Prospect of aftershock activity (see below)
- Characteristics of earthquake derived from data analysis
- Results of mobile observations

Notes: English versions of the Prompt Report and information on the prospect of aftershock activity are not available on the website as of April, 2009.

Prospect of Aftershock Activity

When a large earthquake occurs, a sequence of smaller earthquakes usually follows it. The largest earthquake is called the mainshock, while the smaller ones are referred to as aftershocks.

In the event of a large earthquake, JMA announces the prospect of aftershocks to the public to enable appropriate measures to be taken.

<Example content of a report on the prospect of aftershock activity>

★Comparison of the quake with previous ones
Example…「今回の地震の余震活動は、過去の事例に比べて、極めて活発な部類に属します。」
The level of earthquake activity is very high compared with previous occurrences.

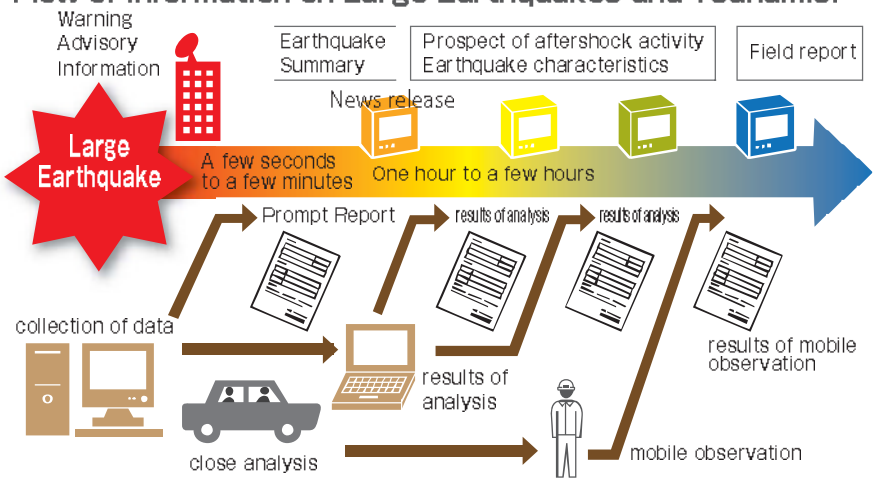
★Current status of aftershocks
Example…「余震活動は時間の経過とともに減衰しているものの、一時的に活発化しています。」
The frequency of aftershocks will decrease over time, but may sometimes increase.

★Aftershock vigilance period
Example…「今後１週間程度は」
A week from the present time

★Expected seismic intensity of aftershocks
Example…「震度６弱、ところによっては震度６強の揺れとなる余震が発生するおそれがあります。」
Large earthquakes with strong shaking and a seismic intensity of 6-lower or 6-upper may occur.

★Things to be careful of
Example…「本震によって強い揺れとなった地域では、余震によって家屋の倒壊や土砂崩れなど、さらに被害が拡大するおそれがありますので、やむを得ない事情がない限り危険個所には立ち入らないなど厳重な警戒が必要です。」
Pay attention to landslides and building collapse as a result of aftershocks.

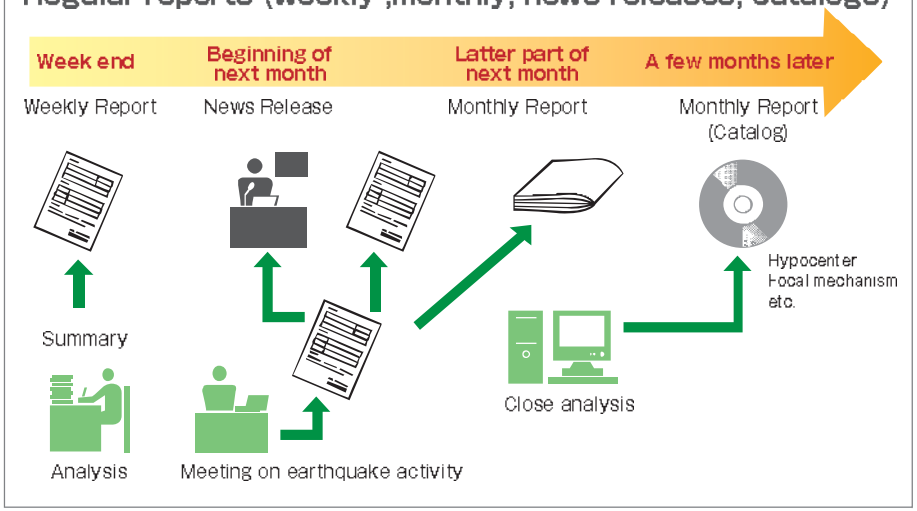
Flow of Information on Large Earthquakes and Tsunamis.



Regular reports on earthquake activity

JMA announces summary of earthquake activities on a weekly and monthly basis. Weekly and monthly reports are published on the JMA website. In addition, the Agency issues the monthly summary as news releases to the public in the beginning of the month.

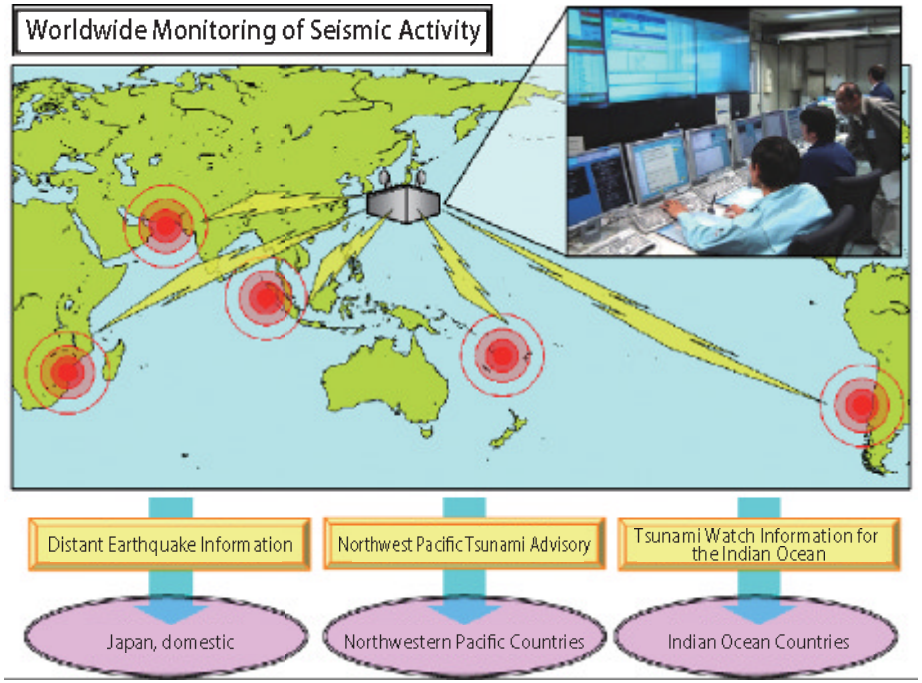
Regular reports (weekly ,monthly, news releases, catalogs)



6 Distant Earthquake Information and International Tsunami Advisories

JMA monitors seismic activity not only around Japan but also worldwide. If a tsunami generated by a distant earthquake is expected to hit the Japanese coast and possibly cause disastrous conditions, JMA issues Tsunami Warnings/Advisories in the same way as for local tsunamis. When a major earthquake occurs somewhere far from Japan, the Agency issues Distant Earthquake Information to the public.

Tsunamis spread ocean-wide regardless of the borders of countries, and can cause serious damage in multiple coastal areas. In order to protect human life and property against tsunami hazards, we must work together with overseas related organizations. Within a worldwide framework for a tsunami warning system, countries exchange observational data and information to enable earthquake/tsunami detection and measures against expected tsunamis as early as possible. Japan has a wealth of experience and knowledge on tsunamis, and JMA, in such an international partnership role, plays a major part in contributing to tsunami disaster management measures in other countries. When a large earthquake occurs in the Sea of Japan, the northwestern Pacific region or the Indian Ocean, the Agency analyzes the related observation data and quickly provides International Tsunami Advisories to the countries in each region. These advisories contain information on the earthquake and the possibility of tsunamis, and are used in the recipient countries for the implementation of emergency action such as nationwide tsunami warnings and official evacuation.



7 Earthquake and Tsunami Monitoring

JMA collects real-time data from seismometers, seismic intensity meters, gauge stations and other instruments to monitor earthquakes and tsunamis around the clock. When an earthquake causes serious damage, the Agency dispatches the JMA Mobile Observation Team (JMA-MOT) to assess the situation.

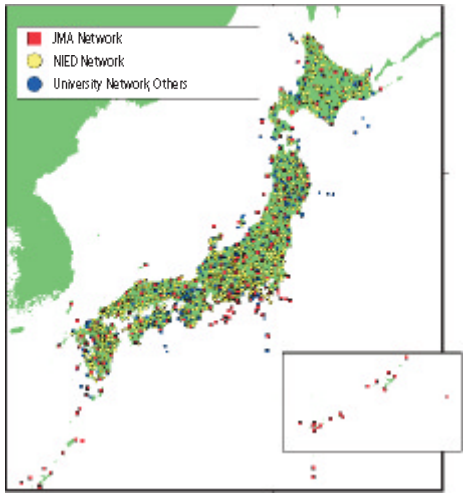
Seismometer Network

When an earthquake occurs, it is important to know its location and magnitude. To achieve this, we need to observe its waves and analyze its hypocenter and magnitude; an instrument used to observe earthquake waves is called a seismometer.

JMA operates a seismic network consisting of about 200 seismometers and collects seismic waveform data in real time around the clock. The Agency also uses seismometers belonging to the National Research Institute for Earth Science and Disaster Prevention (NIED), and issues Earthquake Early Warnings, Tsunami Warnings / Advisories and Earthquake Information.

JMA also collects and analyzes seismic data from NIED, universities and related institutes in order to conduct comprehensive assessment of seismic activity for the 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 the relevant organizations.

◆ Seismometer Network

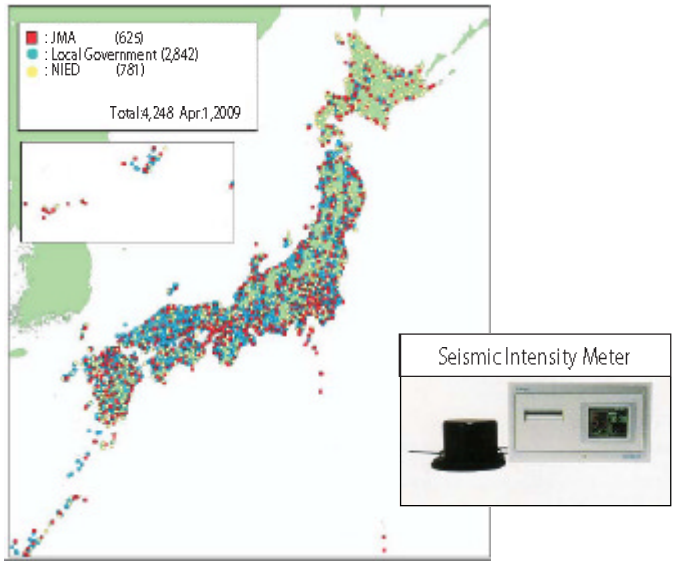


◆ JMA Seismic Station

Seismic Intensity Network

A seismic intensity meter is an instrument that measures and records the seismic intensity of ground motion. JMA has installed about 600 seismic intensity meters throughout the country, and also collects seismic intensity data from another 3,600 stations (as of Apr. 1, 2009) operated by local governments and the National Research Institute for Earth Science and Disaster Prevention (NIED). These data are used for Earthquake Information issued by JMA.

◆ Seismic Intensity Network



Tsunami Monitoring Network

When tsunamis are observed, JMA issues tsunami observation information including observation points, tsunami heights and expected times of arrival. The Agency operates about 70 tidal gauge stations and also collects real-time sea-level data from stations operated by the Ports and Harbors Bureau (Ministry of Land, Infrastructure, Transport and Tourism), the Geographical Survey Institute and the Japan Coast Guard. Currently, JMA issues tsunami information using data from about 170 stations.

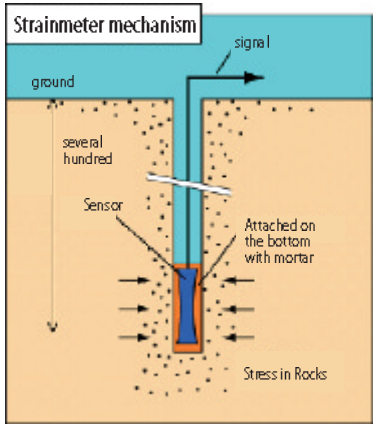
◆ Stilling-well Type Gauge Station

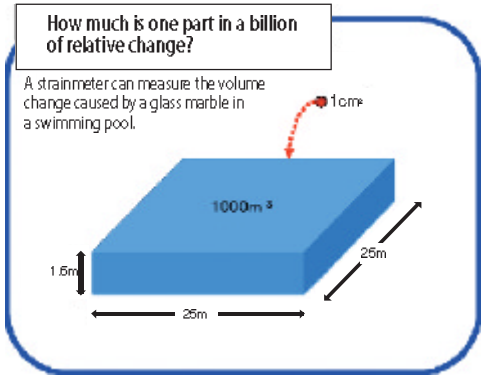
◆ Acoustic Type Gauge Station

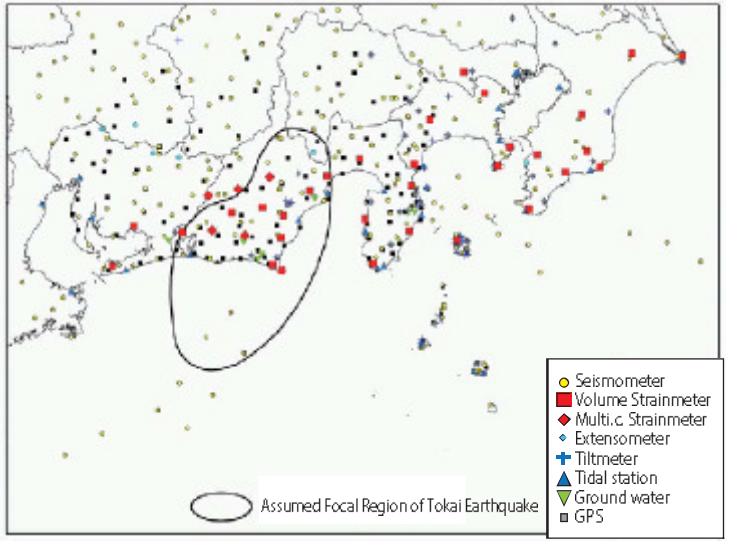
Observation systems for the Tokai Earthquake

Various kinds of instruments, including seismometers, strainmeters and GPS equipment, are installed in and around the assumed focal region of Tokai Earthquake (see the figure below). The observational data in collaboration with related institutes are continuously transmitted to JMA.

Strainmeters play an important role in detecting potential pre-slip movement that may be a precursor to the Tokai Earthquake. They measure very minute expansions and contractions in underground rock. A cylindrical sensor is set at the bottom of a borehole several hundred meters in depth. A strainmeter can detect a relative change of one part in a billion of crustal expansion or contraction. This is equivalent to measuring the volume change caused by a glass marble in a swimming pool.





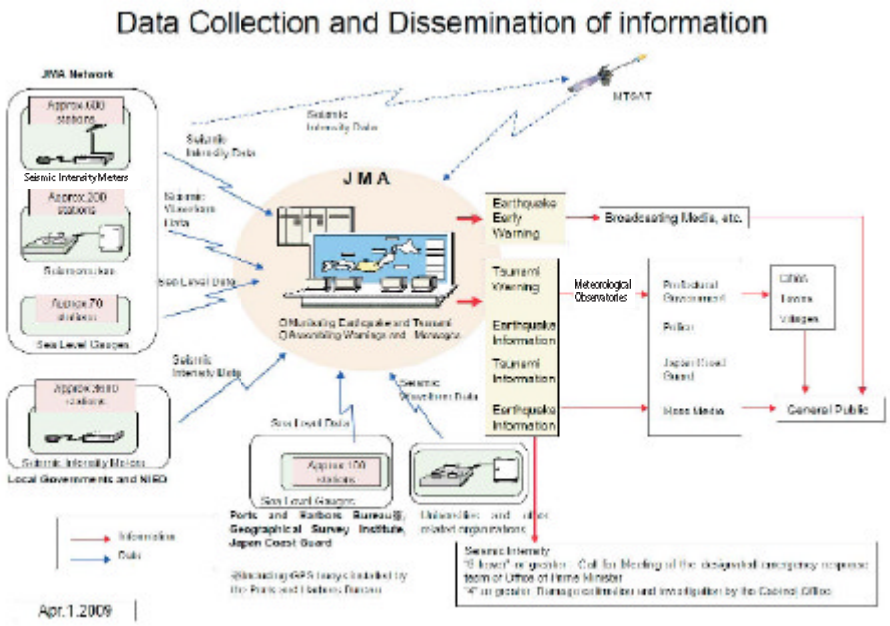


These observations are maintained under joint cooperation effort with the Geographical Survey Institute, Japan Coast Guard, the University of Tokyo, Nagoya University, National Research Institute for Earth-Science and Disaster Prevention, Advanced Industrial Science And Technology, Shizuoka Prefecture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

8 A Data Collection and Processing System for Assured Communication

JMA monitors seismic activity and issues Warnings/Advisories and information on a 24-hour basis. To provide these resources urgently and precisely, JMA needs to collect various seismic data and analyze them quickly. To this end, the Agency operates a comprehensive system called EPOS (the Earthquake Phenomena Observation System). This is responsible for issuing Earthquake Early Warnings, Tsunami Warnings/Advisories, Earthquake Information and Information on the Tokai Earthquake.

Warnings/Advisories and information issued by JMA are transmitted to disaster management authorities, local governments and the broadcasting media over a nationwide computer network immediately. Disaster management authorities and local governments take action to mitigate disasters based on these resources. Such action is also announced to the public through the media and the Internet.



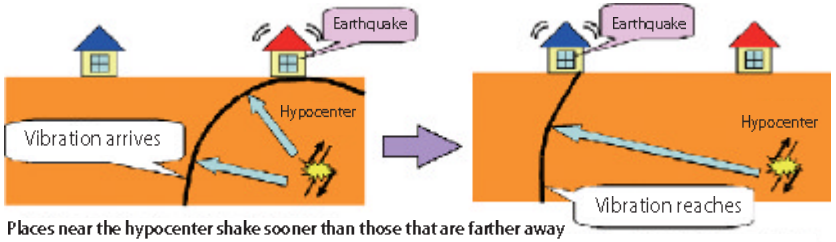
9 Basic knowledge about earthquake and tsunami

Earthquakes and Shaking

What is an earthquake? When people feel the ground shake, they exclaim, "It's an earthquake!" Strictly speaking, what they are feeling is ground motion caused by an earthquake. As a technical term, *ground* motion is used to distinguish this movement from the earthquake itself.

An earthquake is a destructive slip movement inside a rock plate deep under the ground. We call the plane of this movement a *fault*, and the point at which a destructive slip movement starts is called the *hypocenter*.

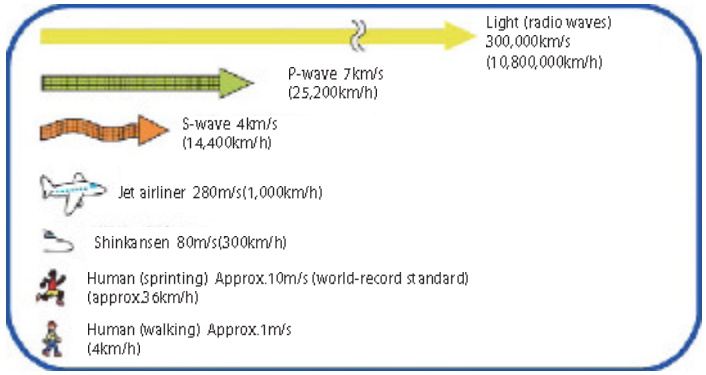
Such destructive slip movements cause vibration that propagates in every direction. Since vibration travels in a wave formation, its movement is called a *seismic wave*. When the vibration reaches the ground surface, people become aware of earthquake motion. Thus, not all places on the surface of the ground shake at the same time. Locations closer to the hypocenter shake first, while distant areas shake later.



Places near the hypocenter shake sooner than those that are farther away

Seismic waves

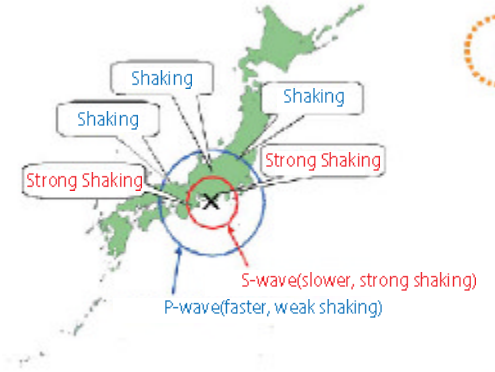
Seismic waves can be either primary waves (P-waves) or secondary waves (S-waves). S-waves propagate more slowly than P-waves, but have a high amplitude and cause damage. P-waves travel at about 7 km/s (25,200 km/h), while S-waves move at about 4 km/s (14,400 km/h). At a point 50 km from the hypocenter, for example, a P-wave will arrive at about 7 seconds after the start of the quake, and an S-wave will arrive at about the 13-second point.

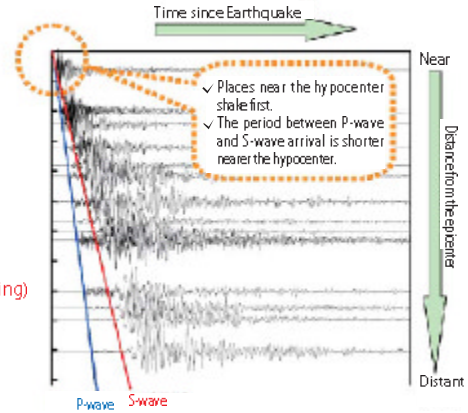


Catching seismic waves

How can we find out where an earthquake occurs ?

Vibration propagates as a wave, so the farther a point is from the hypocenter,the later the wave arrives. As a result, it we can pinpoint where earthquake motion appears first among many monitoring sites (seismometers),the hypocenter can be assumed to near that site. In fact,hypocenters are located by considering the subterranean structure (i.e., the structure of the earth' s crust) and comparing differences in the appearance times of P-waves and S-waves.



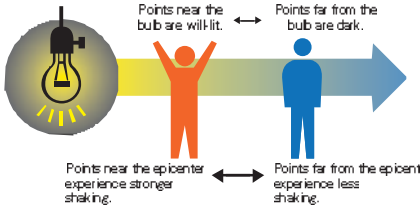


Seismic Intensity and Magnitude

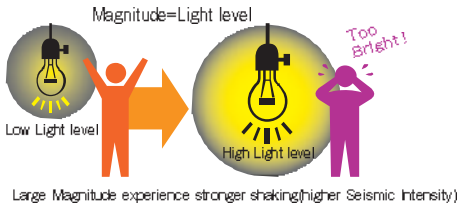
Seismic intensity and magnitude are easily confused because both have similar values. In this section, we explain the difference between them.

Seismic intensity describes the scale of the ground motion at a particular location. It varies with the distance from the epicenter and the surface geology at each point. JMA' s seismic intensity scale has 10 degrees (0 (imperceptible), 1, 2, 3, 4, 5-lower, 5-upper, 6-lower, 6-upper, 7).

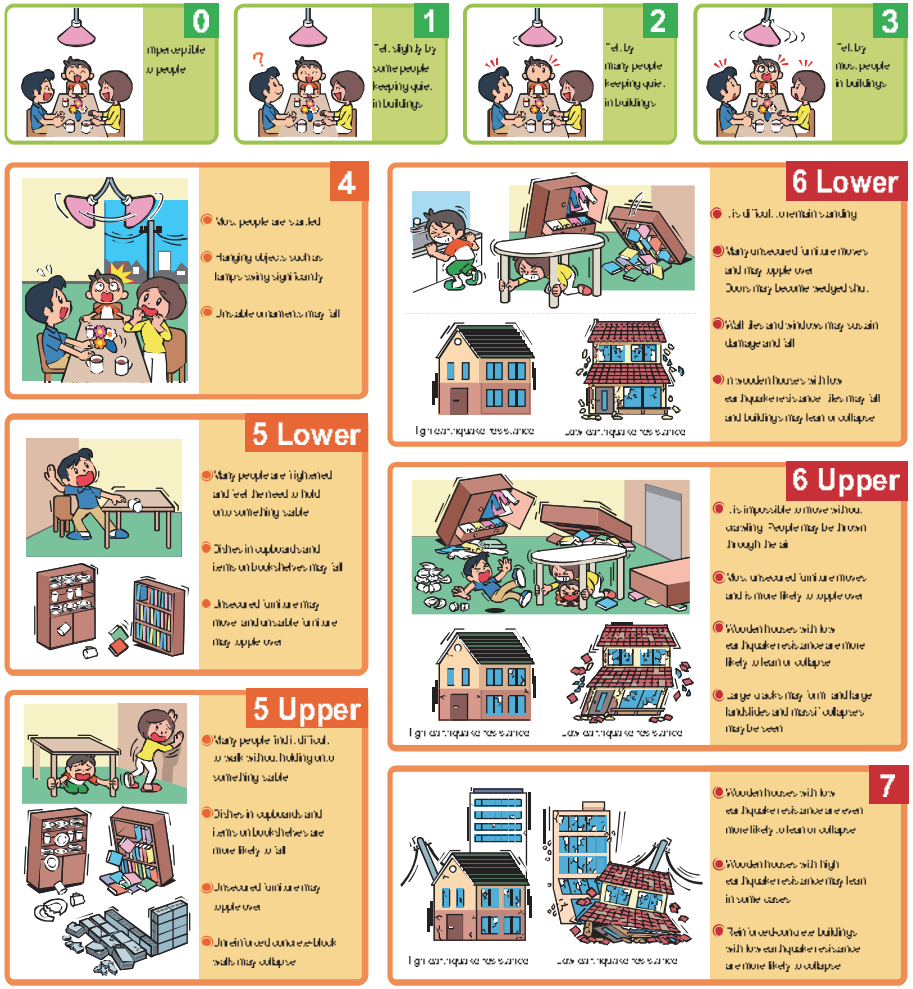
Magnitude is a numerical value that represents the scale of a fault slip underground. Large earthquakes have high magnitude.



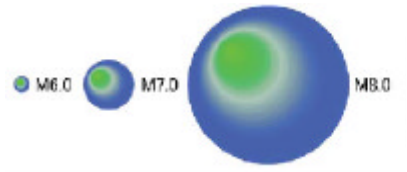
◆ Image of the relation between distance from hypocenter and Seismic Intensity



◆ Image of the relation between Magnitude and Seismic Intensity.



◆ Summary of JMA Seismic Intensity Scale Tables



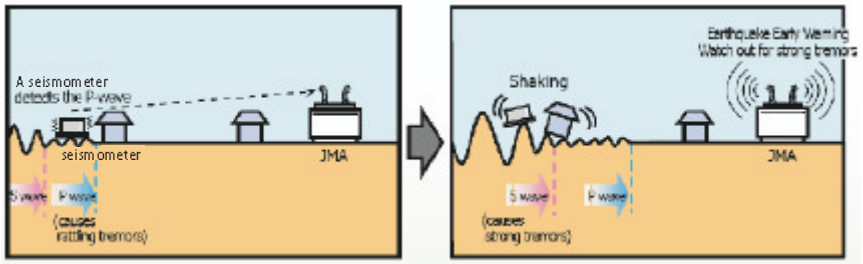
The volume of each ball here represents earthquake energy. A 1-degree increase in magnitude means a 32-fold increase in the energy of the earthquake.

◆ Magnitude and Energy of earthquake

Principle of Earthquake Early Warnings

Earthquake Early Warnings (EEWs) are issued slightly after an earthquake occurs. They are not earthquake predictions which tell us occurrence of earthquake in advance.

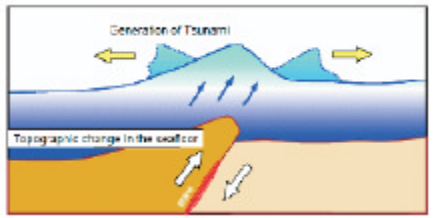
As soon as an earthquake occurs, the EEW system uses seismometers located near the epicenter to calculate the hypocenter, magnitude and P-wave data detected by the area that will be subjected to strong shaking, and provides a first announcement. EEWs are transmitted promptly. A sophisticated observation system to detect seismic waves quickly, technology that enables forecasting from very weak shaking and communication technology for prompt dissemination are the elements that enable JMA to issue EEWs.



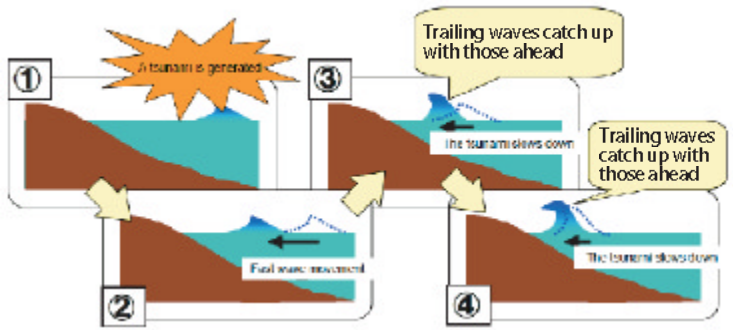
Tsunamis

When large earthquakes occur in ocean areas, the sea floor rises or sinks. Accordingly, massive amounts of water on the sea floor also move up or down, and this movement spreads out in all directions in the ocean. The resulting waves are called tsunamis.

Tsunami waves become slower as the sea becomes shallower. As a result, trailing waves catch up with those ahead near the coast, and the tsunami grows much higher. Even it a tsunami does not seem very high in offshore areas, it can turn into a big wave near the coast. If you feel an earthquake in a coastal area or if a Tsunami Warning is issued, evacuate immediately to high ground. Under no circumstances should you go to the seashore to see the tsunami.

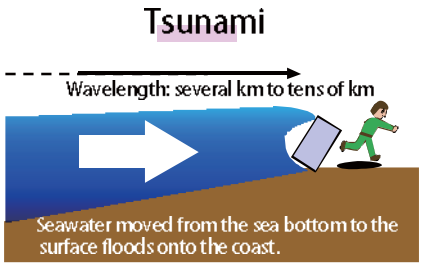


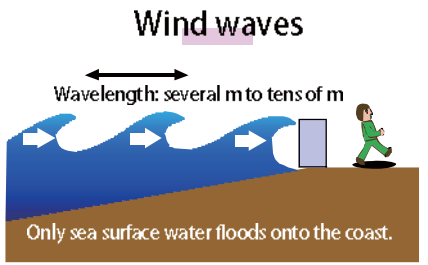
◆ Mechanism of Tsunami Generation



Difference between Tsunamis and Wind Waves

Unlike wind waves, tsunamis are long-period waves. They occur when huge amounts of seawater come from the sea bottom to the surface, and flood coastal areas. When tsunamis run up onto land, they wash away many things with the force of their waves. When they return to the sea, strong undertows drag driftage (such as the debris of destroyed houses) into the sea. Their destructive power is so great that inundation only 50 cm deep caused by tsunami is capable of causing serious damage.



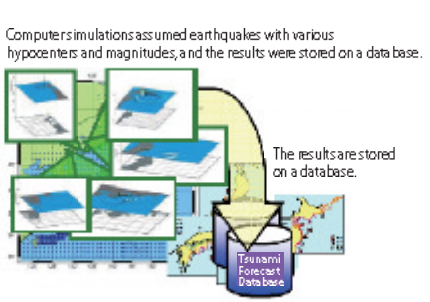


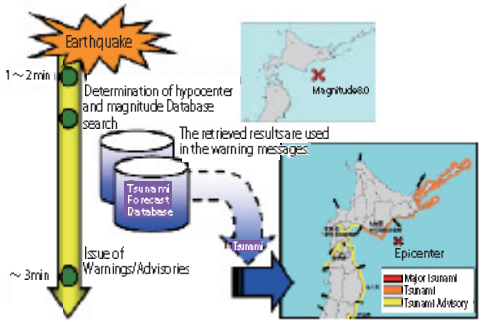
Method of Tsunami Warning

When a large earthquake occurs in a sea area, JMA issues a Tsunami Warning/Advisory. A numerical simulation technique is used to estimate tsunami potential and propagation.

After an earthquake occurs, Tsunami Warnings/Advisories must be issued immediately to enable evacuation before the wave strikes coastal areas.

To enable immediate issuance of Tsunami Warnings/Advisories, JMA has conducted computer simulation of tsunamis with earthquake scenarios involving various locations and magnitudes, and the resulting information on tsunami arrival times and heights is stored on a database. If a large earthquake occurs, the operation system quickly calculates its hypocenter and magnitude, searches the tsunami database referring to these calculations, and selects the closest-matching results from the database. Using the estimated height of the tsunami for each coastal region, JMA issues a Tsunami Warning/Advisory.





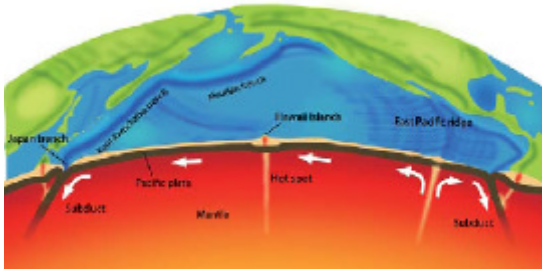
Why do earthquakes occur? - Plate tectonics -

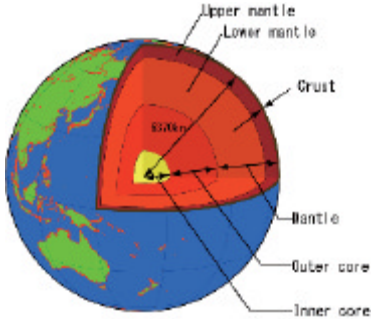
Earthquakes stem from fractures between blocks of rock under the ground that undergo fault motion. Why do faults move? Imagine how a hard material cracks. When an external force is applied to it beyond a level it can bear, it will give way. In the same way, forces act on rock under the ground.

Why, then, do forces act on rock under the ground? This is explained by a theory called plate tectonics.

There are shell (or layer) structures inside the earth. From the center to the outside, these are the core (inner and outer), the mantle (lower and upper) and the crust. Sections of crust and the upper mantle beneath them are called plates, and ten or more of these cover the earth's surface.

The plates float on the mantle, which moves very slowly in line with convection inside the earth. Accordingly, the plates move very slowly too. As a result, they collide with each other. Around the collision area, large forces act on the plates; these are the forces that cause earthquakes.

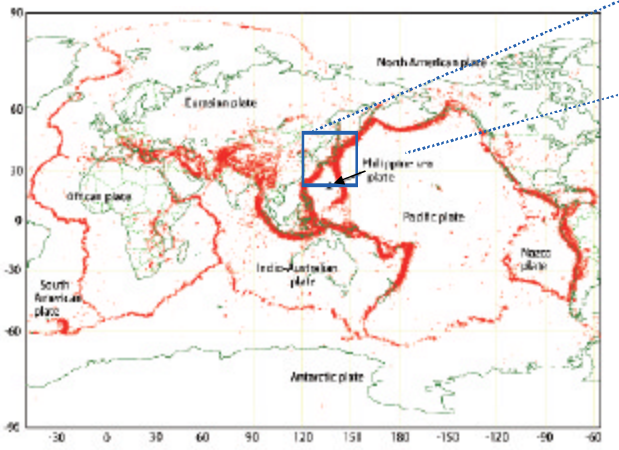




Distribution of Earthquakes —Interplate and Intraplate—

The picture to the right shows the distribution of earthquakes worldwide. It can clearly be seen where earthquakes occur and where they do not. Many occur near the boundaries of plates.

However, they are found not only near boundaries but also inside the plates themselves (e.g., Hawaii and inland China).



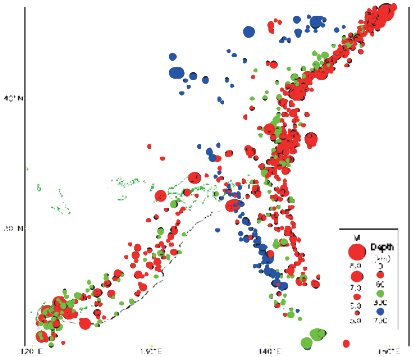
Distribution of earthquakes around the World (data from the USGS)

Earthquakes around Japan

Around Japan, oceanic plates called the Pacific Plate and the Philippine Sea Plate subduct beneath the continental plates (the North American Plate and the Eurasian Plate) several centimeters annually. These plate movements cause forces to act in various directions around the country, which is the reason behind the extremely high seismic activity in the area. Around Japan, therefore, oceanic plates subduct beneath continental plates. These continental plates are dragged down as a result, and strain energy is accumulated.

When this strain exceeds a certain level, it causes the continental plates to jump up, and tremors known as interplate earthquakes occur.

Conversely, tremors generated by strain forces within a plate are called intraplate earthquakes. They occur in subducting plates and shallow underground areas of continental plates. Compared to interplate earthquakes, intraplate earthquake occurring in shallow underground areas are relatively small, but can cause serious damage it they occur directly below populous areas.



Distribution of earthquakes around Japan from 1998 to 2008 (data from the Japan Meteorological Agency)

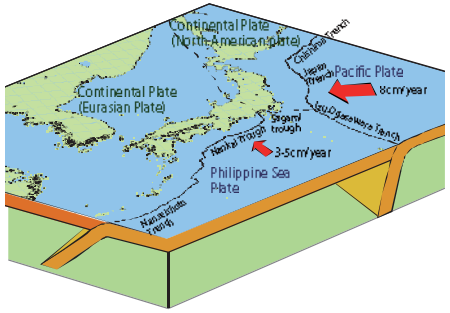
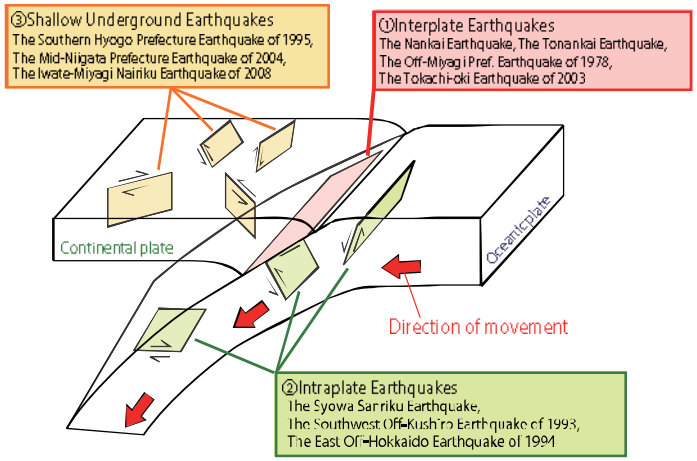


Plate Tectonics around Japan



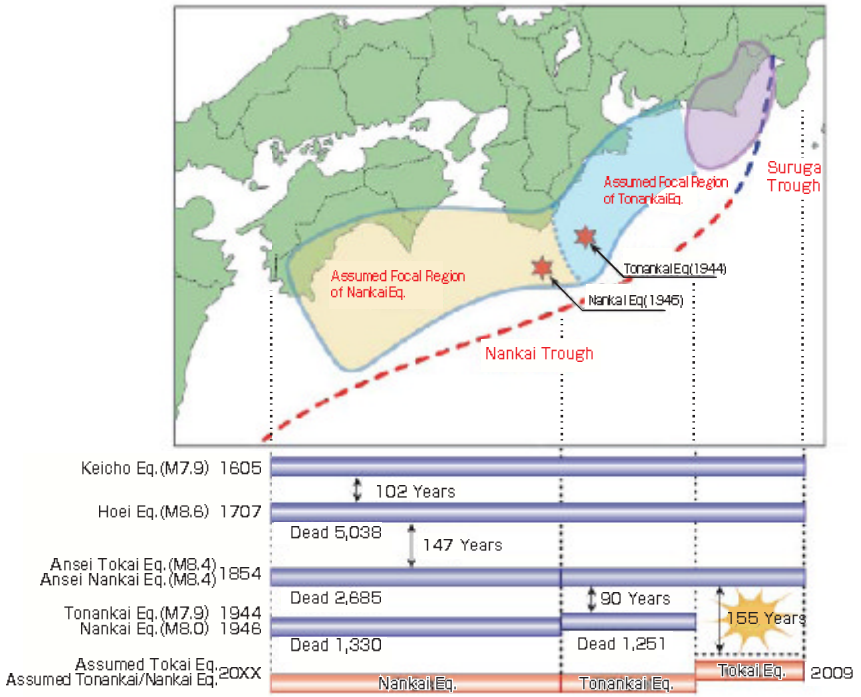
Earthquake Prediction

If we know when earthquakes will occur, we can mitigate the disasters they cause. However, it is currently extremely difficult to predict the occurrence of earthquakes.

Earthquake prediction means pinpointing the timing, location and magnitude of earthquake in advance by scientific means. Since ancient times, various phenomena have been reported as possible precursors of earthquakes after their occurrence. Despite this, earthquake prediction remains at the research stage rather than being operational.

The Tokai Earthquake

The Tokai Earthquake is expected to occur in the near future along the trench near Suruga Bay, and is considered to be as large as M8-class. Large earthquakes of this magnitude have occurred historically every 100 – 150 years in the area from the Suruga Trough in Suruga Bay to the trough off Shikoku Island, and are known as Tonankai/Nankai Earthquakes. However, when the last Tonankai Earthquake (1944, M7.9) and Nankai Earthquake (1946, M8.0) occurred, the crust along the Suruga Trough did not move. Since the trough (in region E of the figure below) has remained motionless for more than 150 years, the Tokai Earthquake is widely expected to occur in the near future.



How is it possible to predict the Tokai Earthquake?

In relation to the Tokai Earthquake, a pre-slip phenomenon (see the figure below) is expected just before the quake itself, and observation systems are in place to detect this slip. If it actually takes place and is successfully detected, JMA will issue warning information on the Tokai Earthquake. However, there is a possibility that the pre-slip could be too slight to be detected by the sensors, so it cannot be said with certainty that the Tokai Earthquake will be predicted.

◆ Why it is thought possible to predict the Tokai Earthquake scientifically

- It is expected to be accompanied by precursory phenomena.
- Observation systems are in place to detect these phenomena.
- There are guidelines on deciding based on the pre-slip model whether detected anomalous phenomena are precursory in nature or not.

Tokai Earthquake Generation Scenario

The Tokai Earthquake is expected to occur with the following sequence:①Accumulation of strain,② Deceleration of subsidence,③Pre-slip,④Occurrence of Tokai Earthquake (see the figure below).

Pre-slip is a phenomenon where part of the hypocentral region (the hard bonded plate boundary in the case of the Tokai Earthquake) peels off and begins to slip.

The key to predicting the Tokai Earthquake is the detection of signs of pre-slip. JMA monitors unusual movement that may accompany pre-slip using strainmeters to predict its occurrence.

◆ Tokai Earthquake Generation and Pre-slip Scenario