Earthquakes and Tsunamis
Observation and Disaster Mitigation

Cover: Seismic Intensity map of the 2016 Kumamoto Earthquake (Apr. 16, M7.3)
Introduction

Earthquake and Tsunami Disasters in Japan

Around a tenth part of all earthquakes occur in and around Japan, making it one of the world’s most earthquake-prone countries.

Japan has suffered serious damage from earthquakes and tsunamis on a number of occasions. Earthquakes cause massive destruction nationwide, with the potential for massive strikes anywhere. Even distant earthquakes far from Japan also can cause damage in Japan due to the tsunami that came across the sea.

Mechanism of Earthquakes in and around Japan

There are three mechanisms behind earthquakes occurring in and around Japan as in the lower figure. All earthquakes can bring down houses and cause landslides in and around residential areas. Large seabed earthquakes can generate tsunami waves that cause massive damage to coastal areas.

Shallow Crustal Earthquake

- 1995 Southern Hyogo Prefecture Earthquake
- 2016 Kumamoto Earthquake
- 2018 Hokkaido Eastern Iburi Earthquake

Inter Plate Earthquake

- 1944 Tonankai Earthquake
- 1946 Nankai Earthquake
- 2003 Tokachi-oki Earthquake
- 2011 off the Pacific coast of Tohoku Earthquake

Intra Plate Earthquake in Oceanic Plates

- 1995 Southern Off-Kushiro Earthquake
- 1994 East Off-Hokkaido Earthquake

Other Information on Earthquake

- Commentary on Earthquakes and Tsunami
- Nankai Trough Earthquake Information
- International Cooperation
- JMA website
- Protect yourself from Earthquake
- Protect yourself from Tsunami

Note:

- Notes when you use the information
- M: Magnitude (overall earthquake scale)
- JMA Seismic Intensity Scale
- \( m \): Moment Magnitude
- \( I_{MS} \): Moment Magnitude
- 3: The JETI (Japanese Earthquake and Tsunami Information) Group
- Earthquakes exceeding M6 in the JMA Earthquake Catalog (1923–2020)

Major earthquakes and tsunami in last 30 years (1991 – 2020) and resulting damage
Seismic intensity meters measure the intensity of earthquake shakings as observed Seismic Intensity values based on acceleration records. JMA manages around 700 such meters nationwide, and also collects Seismic Intensity data from another 3,700 stations operated by local governments and NIED⁷. These data are used for Earthquake Information issued by JMA.

Seismic Intensity Meters of JMA are equipped with satellite communications system that enables data transmission in the event of landline malfunction. If an earthquake causes serious damage, JMA assesses the integrity of its Seismic Intensity meters and/or sets up temporary observation sites as necessary.

Seismometers

JMA operates a seismic network with about 100 seismometers to monitor seismic activity. Among these, accelerometers and velocity seismometers are used to identify/analyze seismic waveforms for Seismic Intensity Information and Earthquake Early Warnings, and transmit Seismic Intensity data and other analytical data as well as seismic waveform data to JMA. These seismic observation facilities are equipped with satellite mobile phone communication capability for backup, and have a power supply that can keep the whole system operational for about 72 hours in the event of power failure.

For the issuance of Earthquake Early Warnings, Tsunami Warnings/Advisories and Earthquake Information, JMA also uses seismic data observed using seismometers managed by other organizations (such as NIED, JAMSTEC⁸ and universities).

Seafloor observation networks

Earthquakes can occur both at land and under the sea. In particular, the plate boundaries at which megathrust earthquakes occur are mostly located under the sea bed. Against this background, data from seafloor seismometers are highly useful in the monitoring and early detection of earthquakes in such areas. Tsunami meters on the seafloor are also helpful to detect tsunami waves before they reach coastal areas.

JMA, NIED and other organizations operate cable ocean-bottom seismometers and tsunami meters along the Japan Trench and the Nankai Trough. Data from both offshore and onshore stations are sent to JMA and used for the issuance and updating of Earthquake Early Warnings and Tsunami Warnings/Advisories.

Tide Gauges

JMA 75
others 99

GPS buoys

JMA 6
others 18

Ocean-bottom Tsunami Meters

JMA 6
others 210+

When tsunamis are detected, JMA issues tsunami observation information containing data on arrival times and the highest waves observed at each observation station. In coastal areas, JMA operates about 80 tide gauges and also collects real-time sea level data from gauges operated by PHB/MLIT⁶, GSI⁴ and JCG⁵ and other organizations. Currently, JMA issues Tsunami Information (Tsunami Observations) using data from about 170 stations.

JMA also uses about 20 GPS buoys (managed by PHB/MLIT) and about 210 Ocean-bottom Tsunami Meters (JMA, NIED, JAMSTEC and ERI⁶) for Tsunami Information (Tsunami Observations at Offshore Gauges) as well as warning updates.

Strainmeters

JMA 25
others 14

To detect crustal deformation caused by slow slip and other phenomena suggesting changes in plate coupling, JMA collects observational data from strainmeters in real time (including data provided by AIST⁷ and Shizuoka prefectural government). These data are used to issue Nankai Trough Earthquake Information.

At Minami-Torishima Island, JMA operates a tsunami meter for early detection of tsunami coming from far away.

*As of Jan 1, 2021
Flow of Warnings/Information

From Observation Data to Information

JMA collects data from its own observatories and those of other organizations in real time and monitors earthquakes and tsunamis on a 24/7 basis under the Earthquake Phenomena Observation System (EPOS).

When an earthquake is detected, JMA immediately determines its scale, the location of its epicenter and the risk of tsunami. Based on this information, JMA creates and issues Earthquake Early Warnings, Tsunami Warnings/Advisories and various other types of information.

Mirror-operation centers are run in Tokyo and Osaka so that warnings and information can still be issued if one is seriously damaged in a large-scale disaster.

From Information to Disaster Mitigation

JMA’s various types of information on earthquakes and tsunamis are provided in various ways suitable for purpose, and are utilized for disaster mitigation correspondence.

Information that prompts urgent evasive action and evacuation, such as Earthquake Early Warnings and Tsunami Warnings/Advisories, is provided immediately to local residents via TV and radio, mobile phone and loudspeakers of the National Early Warning System (J-ALERT).

Other types of information are provided to central and local government bodies, disaster prevention organizations, the media and other parties, and are also published on the JMA website for use in initial response, checking of damaged areas and resident evacuation/rescue.

At the stage of restoration work by municipalities, related organizations and local residents, careful attention is required to the risk of secondary disasters such as residential collapse and landslides associated with subsequent earthquakes, as well as to forming an accurate and comprehensive picture of the damage. To support planning and implementation in relation to associated tasks, JMA issues Prompt Reports with information including seismic intensity distribution, the current situation and prospects for earthquake activity/tsunami as well as notes on disaster mitigation. JMA staff also provide commentary at disaster management headquarters and press briefings.
Timing of Warnings/Information

Earthquake Early Warning

Detect seismic waves immediately after an earthquake and issue EEWs within seconds

- The EEW process is fully automatic.
- "Warning" (urging self-protection against strong shaking) and "Forecasts" (for automatic control of trains/plant equipment and the like) are issued.

Several seconds

Earthquake Early Warning

1 min. 30 sec.

Seismic Intensity Information

Tsunami Warning/Advisory

Issue Tsunami Warnings/Advisories within around 3 minutes

- 24/7 monitoring of earthquakes and tsunami
- Prior simulation of tsunami under various conditions for creation of a database to be referenced for prompt information issuance
- Qualitative (rather than numerical) expression of tsunami heights (e.g., “Huge” and “High”) after earthquakes with magnitudes of M6 or more
- Updating of Tsunami Warning/Advisory and numerical indications of expected tsunami heights once the earthquake magnitude is determined
- Application of tsunami observation data to estimation and updating of Tsunami Warnings/Advisories

3 min.

Tsunami Warning/Advisory

Estimated Tsunami Arrival Times and Heights
High Tide Times and Estimated Tsunami Arrival Times for individual locations

OR

Earthquake Information

5 min.

15 min.

Estimated Seismic Intensity Distribution Map

Tsunami Information (Tsunami Observation at Offshore Gauges)

Tsunami Information (Tsunami Observations)

20 - 30 min.

Information on Long-Period Ground Motion

Nankai Trough Earthquake Extra Information (Under Analysis)

1 - 2 hrs.

Tsunami Warning/Advisory (cancellation)

Nankai Trough Earthquake Information

Investigate the earthquake activity and crustal deformation around the Nankai Trough and issue assessment as extra information

1 week

Report & Press Release (Prospect of seismic activity)

Report & Press Release (Prospect of seismic activity)

Publish reports containing information and commentary on earthquake and tsunami details

Prompt Report & Press Release

Earthquake Information

Issue information timely on hypocenter, M, seismic intensity, etc.

Nankai Trough Earthquake Extra Information (Megathrust Earthquake Alert)

1 - 2 hrs.
EEW: Earthquake Early Warning

Earthquake Early Warnings (EEWs) provide advance notice of estimated Seismic Intensities and expected arrival times of principal motion just after an earthquake occurs. Although strong motion hits within just a few tens of seconds, EEWs can be utilized in various situations to mitigate earthquake-related damage by providing precious seconds before shaking starts.

How it Works

When an earthquake occurs, seismic waves propagate from its focal point (i.e. hypocenter). The main types are primary waves (P-waves) and secondary waves (S-waves), the latter of which propagate more slowly (4 vs. 7 km/s) but are much stronger and can cause far more damage.

JMA analyzes data from seismometers that detect P-waves near the hypocenter and estimates the hypocenter location, magnitude and expected seismic intensity. If the results meet set criteria, EEW Warnings and Forecasts are issued. The process is automatic and rapid, enabling EEW output before the arrival of S-waves.

If strong motion is detected by a seismometer, JMA predicts local strong shaking and issues EEWs via the automatic processing system to warn people of imminent seismic motion.

The EEW system is generally based on science and technology for analysis and estimation, observation systems capable of quickly detecting the occurrence of an earthquake, and information and communications technology for prompt delivery of EEWs.

Appropriate Preparation and Response

It is important to understand the different issuance criteria/characteristics and respond appropriately.

Warnings

Warnings are issued widely through various media such as not only TV and radio, but also cellphones and smartphones to help people protect themselves from strong shaking.

It is advisable to prepare in advance by creating a safe space and implementing drills for immediate self-protection in the event of a Warning.

To support the rapid implementation of self-preservation measures, TV/radio and cellphones/smartphones emit individually unique alarms. Get to know the sounds they make so that you will recognize an alert as soon as it is issued.

Forecasts

Forecasts are issued quickly even when the accuracy of available information remains limited, and are updated iteratively with increasing precision over time. As a result, Forecasts can provide alerts of shaking before Warnings in some cases.

Some corporate operators licensed for forecasting predict seismic intensities and times at which strong shaking will start in specific locations based on forecast data from JMA. This information can be used to enable advance preparations such as mechanical control of machinery/equipment and issuance of automatic announcements in indoor environments.

Users can subscribe to these forecasts by contacting the relevant licensed company or installing dedicated applications.

“Warnings” and “Forecasts”

<table>
<thead>
<tr>
<th>Categories</th>
<th>Criteria</th>
<th>Details</th>
<th>Features</th>
<th>Transmission methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warnings</td>
<td>For estimated $f_{p_k}$ or greater. (Provided for areas where $f_{p_k}$ is expected to be 4 or greater)</td>
<td>Estimated origin time and hypocenter</td>
<td>In principal, issued only once for each earthquake (issued if expected $f_{p_k}$ in areas where warnings are not issued becomes 5 or greater.)</td>
<td>TV, radio</td>
</tr>
<tr>
<td></td>
<td>For estimated $f_{p_k}$ or greater</td>
<td>Areas where $f_{p_k}$ is expected to be 4 or greater</td>
<td></td>
<td>Cellphone, smartphone (Emergency Alert Email), disaster management radio communications systems</td>
</tr>
<tr>
<td>Forecasts</td>
<td>For estimated $f_{S_k}$ or greater</td>
<td>Estimated origin time, hypocenter and magnitude</td>
<td>Issued whenever predictions change (sometimes 10 times or more)</td>
<td>EEW receivers, dedicated systems, EEW reception application for smartphone (provided private company)</td>
</tr>
<tr>
<td></td>
<td>For estimated magnitude is 3.5 or greater</td>
<td>Areas where $f_{S_k}$ is expected to be 4 or greater, estimated $f_{S_k}$ and arrival time of principal motion with $f_{S_k}$ or more</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EEWs are either Warnings or Forecasts. Warnings contain simple information to help people protect themselves from strong shaking, and are widely disseminated through various media such as TV and cellular phones. Forecasts are more detailed and frequently updated for use in various situations such as automatic control of trains and plant facilities.

In areas close to the hypocenter, Warnings may not arrive in time before strong shaking hits.

EEW Seismic Intensity estimations have an error margin of ±1 or so.

Warning accuracy may vary due to calculation with the limited data available immediately after an earthquake.

EEW broadcast (NHK)

NHK alarm can be previewed on the NHK website.

Checking other points to note for response to EEWs on the JMA website (in Japanese only).


![Image](image-url)
Tsunami Warnings/Advisories

Tsunami Warnings/Advisories

Immediately after an earthquake, JMA estimates the earthquake’s location/magnitude and potential maximum tsunami heights in coastal regions of Japan with reference to a tsunami database. If damage is expected, Tsunami Warnings/Advisories are issued for the relevant forecast regions within around three minutes of the earthquake.

JMA generally expresses maximum tsunami heights in five quantitative levels. However, it takes time to determine the exact scale of earthquakes with a magnitude of 8 or more. In such cases, JMA issues an initial warning based on the predefined maximum magnitude to avoid underestimation. When such values are used, estimated maximum tsunami heights are expressed in qualitative terms such as “Huge” and “High” rather than quantitatively.

Once the exact magnitude is determined, JMA updates the Warning with quantitatively estimated maximum tsunami heights, which are included in subsequent tsunami information.

When issuing Tsunami Warnings/Advisories, JMA also provides information on estimated tsunami arrival times and maximum tsunami heights for relevant forecast regions and data on high-tide times and estimated arrival times of the first wave at selected points.

<table>
<thead>
<tr>
<th>Tsunami Forecast Region</th>
<th>Category of Tsunami Warning/Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fukushima Pref.</td>
<td>TSUNAMI WARNING</td>
</tr>
</tbody>
</table>

Estimated arrival times (the time at which a tsunami is expected to hit first in any part of an area) and maximum heights for relevant tsunami forecast regions are indicated.

Tsunami Forecast

JMA issues Tsunami Forecast or Earthquake Information to indicate no tsunami threat in association with an earthquake (pp. 16).

- Maximum tsunami heights may exceed estimates in some regions.
- Estimated initial tsunami arrival times are the earliest predictions for each tsunami forecast region. As the arrival time in each region depends on the location, tsunamis may hit some coastal areas tens of minutes or more after the estimated time.
- Tsunami waves may hit before Tsunami Warnings/Advisories are issued if the source region is near the coast.
- When the exact magnitude is determined or tsunami waves are observed, JMA may update Tsunami Warnings/Advisories.

Approximate relationship between tsunami height and damage (Modified Shuto, 1993)

- Height
  - Aquaculture raft: Damage
  - Fishing boat: Damage begins
  - Wooden house: Partly damaged
  - Stone house: Intact
  - Reinforced concrete building: Intact

- Damage ratio
  - Damage ratio 50%: Moderate
  - Damage ratio 100%: Extreme

- Tsunami control forest
  - Slight: Tsunami buffering / Debris capture
  - Moderate: Tsunami buffering / Debris capture
  - Extreme: Tsunami buffering / Debris capture

- Wooden house
  - Slight: Partial damage
  - Moderate: Destruction
  - Extreme: Destruction

- Stone house
  - Slight: Intact
  - Moderate: Destruction
  - Extreme: Destruction

- Reinforced concrete building
  - Slight: Intact
  - Moderate: Destruction
  - Extreme: Destruction

- Tsunami buffering / Debris capture
  - High tide times

- Tsunami arrival at high tide boosts wave height and increases the scope of potential damage.
Information on Tsunami Observations

When tsunamis are observed at coastal meters, JMA announces arrival times of “first wave” and “maximum wave” of the observed first waves as well as the arrival times and scale of the maximum waves observed as of the times of issuance for each tsunami observation site.

“Information pending”
To prevent delays in evacuation, JMA does not issue observation/estimation values if the maximum wave height is below the evacuation trigger threshold. When observed tsunamis are smaller than estimated, JMA uses the phrase “information pending” rather than providing actual values to avoid creating a false sense of security in regions where Major Tsunami Warnings and/or Tsunami Advisories are in effect.

**Observation equipment**

- **Coastal observation equipment**
  - **Tsunami meter** Measures the distance between tsunami triggers/waves and the sea surface using observation or radio waves.
  - **Trace Height**: Trace Height
  - **Tide gauge**: Measures the distance between tsunami triggers/waves and the sea surface using observation or radio waves.
  - **Ocean bottom tsunami meter**: Measures the distance between tsunami triggers/waves and the sea surface using observation or radio waves.

- **Offshore observation equipment**
  - **GPS buoy**: Measures the distance to the sea surface in a floating well-coordinated buoy on the sea floor.

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**Tsunami Warning Timeline**

- **Estimation of earthquake location and magnitude**
- **Establishment of initial magnitude and mechanism**
- **Reference to database**
- **Issue Tsunami Warning/Advisory**
- **Update**

**Coastal Gauges**

- **Normal Sea Level**
- **Tsunami Height**
- **Inundation Depth**
- **Trace Height**
- **Run-up Height**

**Estimation of Tsunami Heights and Arrival Times**

JMA and other public agencies have placed coastal and offshore tsunami meters, and JMA collects data from these stations in real-time. When tsunamis are observed at these stations, JMA announces in tsunami information bulletins and updates or lifts Tsunami Warnings/Advisories.

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**Information on Tsunami Observations**

When tsunamis are observed at coastal meters, JMA announces arrival times and initial movement rise/fall of the observed first waves in coastal areas as well as the arrival times and scale of the maximum waves observed as of the times of issuance for each tsunami observation site.

**What is “tsunami height”?**

Tsunami height figures in JMA Warnings/Advisories refer to the height of the wave crest from normal sea level (i.e., that in the absence of tsunami conditions) at the coast. JMA also references “run-up height” (the height of a tsunami running inland) and “trace height” (the height of tsunami-related traces such as mud marks on inland structures). These figures may exceed the tsunami height.
When an earthquake occurs, JMA promptly issues related information based on seismological observations and determines its time of occurrence, hypocenter, and magnitude.

**Seismic Intensity Information**
This information specifies the time of earthquake occurrence and identifies sub-prefectural regions where $I_{eq}$ 3 or greater has been observed (issued within 90 seconds of the earthquake).

*This information is posted on the JMA website when $I_{eq}$ 3 or greater is recorded.*

**Earthquake Information**
This information specifies the hypocenter and magnitude, and identifies sub-prefectural regions and cities/towns/villages where $I_{eq}$ 3 or greater has been observed and those where the estimated $I_{eq}$ is 5- or greater but related observation data are incomplete.

*In JMA XML telegrams, "Earthquake and Seismic Intensity Information" is combined with "Information on Seismic Intensity at each site".

**Information on Seismic Intensity at each site**
This information specifies the hypocenter and magnitude, and identifies individual sites where $I_{eq}$ 3 or greater has been observed and those where the estimated $I_{eq}$ is 5- or greater but related observation data are incomplete.

**Estimated Seismic Intensity Distribution Maps**
When the observed maximum $I_{eq}$ is 5- or greater, JMA issues Estimated Seismic Intensity Distribution Maps showing expected Seismic Intensity based on observation data in consideration of site amplification to areas where $I_{eq}$ 4 or greater has been estimated.

**Summary of the JMA Seismic Intensity Scale**

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Description</th>
</tr>
</thead>
</table>
| 0 | Earthquake felt only by majority of people in close proximity to the epicenter.
| 1 | Felt by many people, noticeable even in buildings. Earthquake and slight shaking.
| 2 | Felt by most people, noticeable even in buildings. Strong earthquake and noticeable shaking.
| 3 | Felt by most people in buildings. Strong earthquake and noticeable shaking.
| 4 | Felt by most people in buildings. Strong earthquake and noticeable shaking. Buildings may shake violently.
| 5 | Felt by most people in buildings. Strong earthquake and noticeable shaking. Buildings may shake violently. Buildings with low earthquake resistance may collapse.
| 7 | Strong earthquake and noticeable shaking. Buildings may shake violently. Buildings with low earthquake resistance may collapse. Buildings with high earthquake resistance may suffer large damage.

Seismic Intensity measured at observation sites even in the same city or block may differ with a margin of ±1 because ground motion is affected by ground conditions and topography.

Earthquakes in very shallow parts of the crust may be felt even if their magnitude is small. Tremors are often felt over a limited area, and those with a Seismic Intensity of 1 or less may not be observed if there is no Seismic Intensity meter nearby. In such cases, no earthquake information is issued.

As estimated intensity values have a margin of error, these maps should be used to determine the approximate extent and distribution of strong ground motion rather than for focus on the estimated values in each grid.
Information on Long-Period Ground Motion

When a major earthquake occurs, long-period ground motion may cause greater damage to upper floors of buildings than at ground level. Information is provided to clarify the characteristics of long-period shaking in such structures and support mitigation of related damage.

Long-Period Ground Motion

Earthquakes generate ground motion with various periods -- the term given to the time between one wave and the next. Major earthquakes such as the 2011 Great East Japan Earthquake bring notable long-period ground motion (LPGM), which does not attenuate as readily as its short-period counterpart and propagates over great distances. Such shaking is especially amplified and tends to last longer in soft strata such as those found on sedimentary plains.

Artificial structures also have their own natural periods. If the predominant period of ground motion is close to the natural period of a building, the structure resonates and the amplitude increases. As the natural periods of high-rise buildings are longer than those of low-rise types, the former tend to resonate more with LPGM and undergo longer-lasting extreme shaking.

Furniture and fixtures in high-rise buildings subjected to extreme shaking may topple over or shift, and elevators may cease to operate. The amplitude tends to increase on higher floors, causing greater damage.

As the high-rise buildings found extensively on sedimentary plains in metropolitan areas of Japan such as Tokyo, Nagoya and Osaka are vulnerable to extreme shaking in association with LPGM, there are concerns that the anticipated Nanikai trough earthquake could cause large-scale damage in these areas.

Effects of long-period ground motion

Furniture/fixture toppling and shift

In the 2011 off the Pacific coast of Tohoku Earthquake, upper floors of high-rise buildings swayed significantly and fixtures topped over or shifted even in areas far away from the epicenter such as Tokyo.

Elevator and Interior damage

In the Mid Niigata prefecture earthquake in 2004, damage to elevator wires occurred in high-rise buildings in Tokyo (T_{50}) approximately 200 km from the epicenter.

In the 2011 off the Pacific coast of Tohoku Earthquake, high-rise buildings swayed significantly even in Osaka (T_{50}) approximately 700 km from the hypocenter, interior materials and fire doors were damaged, and many people were trapped in stopped elevators.

Oil tank damage

In the Tokachi-oki Earthquake in 2003, petroleum complexes in Tomakomai approximately 250 km from the hypocenter experienced sloshing of liquid in tanks. Floating roofs on tanks sank, and a full surface fire broke out.

Information on Long-Period Ground Motion

JMA provides its Information on Long-Period Ground Motion product (detailing variables including observed LPGM class and seismic waveforms) on its website within around 20-30 minutes of an earthquake.

JMA Intensity Scale for Long-Period Ground Motion

<table>
<thead>
<tr>
<th>Long-Period Ground Motion (LPGM) class</th>
<th>Human perception</th>
<th>Indoor situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>class1</td>
<td>Felt by most people in buildings. Some people are startled.</td>
<td>Hanging items such as lamps and blinds swing significantly.</td>
</tr>
<tr>
<td>class2</td>
<td>Many people find it difficult to walk without holding onto something stable.</td>
<td>Furniture on casters moves slightly. Items in cupboards and bookshelves may fall. Some of unsecured moves and may topple over.</td>
</tr>
<tr>
<td>class3</td>
<td>It’s difficult to remain standing.</td>
<td>Furniture on casters moves significantly. Some of unsecured moves and may topple over. Partition walls may crack.</td>
</tr>
<tr>
<td>class4</td>
<td>It’s impossible to remain standing or move without crawling. People are at the mercy of shaking.</td>
<td>Furniture on casters moves significantly and may topple over. Unsecured furniture moves and may topple over. Partition walls are likely to crack.</td>
</tr>
</tbody>
</table>

As Seismic Intensity data only partially express the strength of long-period shaking on higher floors, JMA is using a four-category intensity scale for LPGM to indicate the strength of shaking in high-rise buildings and the possibility of related damage.

The scale quantifies the effects of shaking in a high-rise building with a natural period of around 1.5 to 8 seconds (approx. 14 stories or more). There are four classes based on degrees of human perception and damage, such as toppling or shifting of furniture and fixtures. The conditions indicated are a rough guide, and actual damage may differ between higher and lower floors due to individual buildings.

Information on Long-Period Ground Motion

Erthquakes producing LPGM class 3 or higher (since Mar. 2013)

<table>
<thead>
<tr>
<th>Date (JST)</th>
<th>Hypocenter</th>
<th>M</th>
<th>LPGM class</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014-11-22 22:08</td>
<td>Northern Nagano Pref.</td>
<td>6.7</td>
<td>6 - 6+</td>
</tr>
<tr>
<td>2015-05-13 06:12</td>
<td>Off Miyagi Pref.</td>
<td>6.8</td>
<td>5+</td>
</tr>
<tr>
<td>2016-04-14 21:26</td>
<td>Kumamoto Pref.</td>
<td>6.5</td>
<td>7</td>
</tr>
<tr>
<td>2016-04-15 00:03</td>
<td>Kumamoto Pref.</td>
<td>6.4</td>
<td>6+</td>
</tr>
<tr>
<td>2016-04-16 01:25</td>
<td>Kumamoto Pref.</td>
<td>7.3</td>
<td>7</td>
</tr>
<tr>
<td>2016-10-21 14:07</td>
<td>Middle Tottori Pref.</td>
<td>6.6</td>
<td>6-</td>
</tr>
<tr>
<td>2018-09-06 03:07</td>
<td>Mid Eki East part, Iwakuni</td>
<td>6.7</td>
<td>7</td>
</tr>
<tr>
<td>2019-06-18 22:22</td>
<td>Off Yamagata Pref.</td>
<td>6.7</td>
<td>6+</td>
</tr>
<tr>
<td>2021-02-13 23:07</td>
<td>Off Fukushima Pref.</td>
<td>7.3</td>
<td>6+</td>
</tr>
</tbody>
</table>

LPGM classes in the 2016 Kumamoto Earthquake (M7.3, Apr. 16, 2016, 01:15 JST) ➤

The maximum Class 4 and motion exceeding Class 1 were observed over a wide area. Class 2 was also observed in northeastern Chiba Prefecture around 900 km from the hypocenter.

➤ How the high-rise building shakes varies depending on its height, shape and structure. LPGM class may not be accurate due to individual building.

➤ The characteristics of shaking in high-rise buildings differ between higher and lower floors. The top of a building may be more severely shaken than scale values suggest.
Commentary on Earthquakes and Tsunami

Prompt Reports and Press Briefings

When a large earthquake with a magnitude of 8.0 or greater occurs, or when Tsunami Warnings/Advisories are in effect, JMA issues Prompt Reports on Large Earthquakes and Tsunamis to provide information on the hypocenter, magnitude, tsunami (if observed), distribution of Seismic Intensity, historical earthquake activity around the hypocenter and other data. If there is a risk of serious damage, JMA issues information on the earthquake and provides important notifications to the public through the media (via news releases) and to disaster management authorities.

Prospect of Seismic Activity – Announcement for Disaster Mitigation after Major Earthquakes

Major earthquakes may be followed by ongoing seismic activity. When further damage is expected (as is often the case after earthquakes with magnitude 5 or greater shaking), JMA details the prospect of further earthquakes in press releases and provides information on the period during which caution is required, expected seismic intensity, and related points to note (such as the presence of nearby active faults and possible major subduction-zone earthquakes). Reporting also includes seismic activity observation data, information on weather conditions and calls for attention to the developing situation.

Other Information on Earthquake

Distant Earthquake Information

JMA monitors seismic activity not only around Japan but also worldwide. When an earthquake with a magnitude of 7.0 or larger or with a remarkable magnitude that may cause significant damage to nearby cities occurs outside Japan, JMA issues Distant Earthquake Information to the public within about 30 minutes after the earthquake occurs. Its content includes the date, time, epicenter and magnitude of the earthquake as well as the estimated impact and observation of tsunami generated by the quake.

Information on numbers of earthquakes and other variables

JMA provides a frequency of earthquakes with maximum seismic intensity 1 or greater, omitting issuance of intensity information of each of earthquakes with maximum seismic intensity 1 or 2, if many earthquakes occur within a short period of time.

When hypocenter and magnitude of significant earthquakes are scrutinized, JMA issues information on update of hypocenter and magnitude.

Information on Seismic Activity in the Eastern Izu District

In the eastern Izu district, seismic swarms related to magma activity have frequently occurred in the past. Based on the data obtained from past activities, JMA evaluates the transition and prospect of further earthquakes in eastern Izu.

If anomalous crustal deformation caused by magma rising is detected and active seismicity is expected, JMA issues information on the maximum possible magnitude and Seismic Intensity of the largest earthquake, the expected number of earthquakes with a Seismic Intensity of 1 or greater, and the expected duration of the activity.

Prospect of Seismic Activity – Announcement for Disaster Mitigation after Major Earthquakes

Major earthquakes may be followed by ongoing seismic activity. When further damage is expected (as is often the case after earthquakes with magnitude 5 or greater shaking), JMA details the prospect of further earthquakes in press releases and provides information on the period during which caution is required, expected seismic intensity, and related points to note (such as the presence of nearby active faults and possible major subduction-zone earthquakes). Reporting also includes seismic activity observation data, information on weather conditions and calls for attention to the developing situation.

Commentary on Earthquakes and Tsunami

Prompt Reports and Press Briefings

When a large earthquake with a magnitude of 8.0 or greater occurs, or when Tsunami Warnings/Advisories are in effect, JMA issues Prompt Reports on Large Earthquakes and Tsunamis to provide information on the hypocenter, magnitude, tsunami (if observed), distribution of Seismic Intensity, historical earthquake activity around the hypocenter and other data. If there is a risk of serious damage, JMA issues information on the earthquake and provides important notifications to the public through the media (via news releases) and to disaster management authorities.

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Nankai Trough Earthquake Information

Nankai Trough Earthquake Information

JMA monitors seismicity and crustal deformation along the Nankai Trough around the clock. If anomalous phenomena are detected or the possibility of an earthquake along the Nankai Trough is considered relatively high, Nankai Trough Earthquake Information is issued as outlined below.

<table>
<thead>
<tr>
<th>Information</th>
<th>Conditions</th>
</tr>
</thead>
</table>
| Nankai Trough Earthquake Extra Information | • When analysis is performed to determine whether anomalies may be Nankai Trough Earthquake precursors  
• When analysis results are issued |
| Nankai Trough Earthquake-Related Commentary | • When analysis results are updated  
• When analysis results are reported at regular meetings of the Nankai Trough Earthquake Assessment Committee (except for Nankai Trough Earthquake Extra Information)  
• Once necessary disaster prevention measures have been taken, information on analysis status and results may be issued in Nankai Trough Earthquake-Related Commentary |

Keywords of Nankai Trough Earthquake Extra Information

Nankai Trough Earthquake Extra Information is issued with the title Nankai Trough Earthquake Extra Information (Megathrust Earthquake Alert) with appended keywords. Examples of keywords and disaster prevention measures are shown below.

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under Analysis</td>
<td>When analysis is underway to determine whether anomalies relate to the Nankai Trough Earthquake</td>
</tr>
<tr>
<td>Megathrust Earthquake Alert</td>
<td>When an earthquake with M8.0 or more is considered to have occurred at the plate boundary in the hypocenter area along the Nankai Trough</td>
</tr>
<tr>
<td>Megathrust Earthquake Attention</td>
<td>When an earthquake with M7.0 or more or an anomalous slow slip is considered to have occurred along the Nankai Trough (except in correspondence with Megathrust Earthquake Alert)</td>
</tr>
<tr>
<td>Analysis Complete</td>
<td>When the results of analysis indicate that the anomalies are not classified into either Megathrust Earthquake Alert or Megathrust Earthquake Attention output</td>
</tr>
</tbody>
</table>

Issuance of Nankai Trough Earthquake Extra Information and Disaster Prevention Measures

Under Analysis
- Take action to protect yourself as necessary
- Pay attention to subsequent information issuance

Megathrust Earthquake Alert
- Remain prepared for an earthquake on a daily basis
- Evacuate to a safe place and stay there for a week in areas where tsunami evacuation may take place

Megathrust Earthquake Attention
- Remain prepared for an earthquake on a daily basis
- No restrictions

Analysis Complete

Anomalous phenomena 5-30 minutes

2 hours

What is the Nankai Trough Earthquake?

The Nankai Trough, which runs from Japan’s Suruga Bay to the Hyuganada sea region, is an oceanic trench where the Philippine Sea Plate subducts underneath the Eurasian plate (continental plate) at a rate of several centimeters a year. In some places, the two plates stick together, causing the lower plate to pull the upper one downward and creating an accumulation of strain. When this build-up exceeds the bearable limit, the upper plate snaps back and a Nankai Trough Earthquake occurs. The Philippine Sea Plate continues to subside along the trough, and the cycle of pulling down and snapping back repeats.

Nankai Trough Earthquakes occur with a cycle of roughly 100-150 years with various repetition intervals and source areas. In some cases, multiple earthquakes occur within a certain period, and in others most of the trough can rupture at once. More than 70 years have passed since the last two megathrust earthquakes in the area (the 1944 Showa Tonankai Earthquake and the 1946 Showa Nankai Earthquake), suggesting that the next may be imminent.

The government’s Central Disaster Management Council has evaluated potential damage from a Nankai Trough Earthquake with M9 (the maximum possible magnitude in scientific estimation). The results suggested a potential seismic intensity of 7 in part of the area from Shizuoka to Miyazaki and tsunami with heights exceeding 10 meters over wide areas of the Pacific Coast from Kanto to Kyushu.

The Nankai Trough Earthquake could occur at any time without the opportunity for issuance of related information in advance.

Even if the potential for Nankai Trough Earthquake occurrence is assessed as higher and related information is issued, the earthquake may not occur.

Nankai Trough Earthquake conditions require urgent response, and may arise at any time.
International Cooperation

International Tsunami Information

Since 2005, JMA has served as the Northwest Pacific Tsunami Advisory Center (NWPTAC) and monitored earthquakes and tsunamis within its Area of Service (AoS), which covers the Northwest Pacific region. When a major earthquake with a magnitude of 6.5 or greater occurs inside the AoS, the NWPTAC provides Northwest Pacific Tsunami Advisories (NWPTAs) to the countries concerned. Advisories report the origin time, hypocenter and magnitude of the earthquake, as well as estimated arrival times and heights of tsunamis at coastal Forecast Points (FPs). Subsequent analysis of seismic observation data revealing the mechanism of the earthquake will be used to perform real-time numerical simulation and issue related NWPTA updates. Information on the height of any tsunami waves observed is also included. JMA has also issued tsunami information for the Sea of Japan to surrounding countries since 2001.

JMA’s international tsunami information helps recipient countries to issue their own domestic tsunami warnings and/or evacuation recommendations.

The NWPTAC is operated under the auspices of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) under the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO/IOC), and contributes to tsunami disaster mitigation systems of Pacific countries in collaboration with the US Pacific Tsunami Warning Center (PTWC), which monitors earthquakes and tsunamis throughout the Pacific region and provides tsunami information accordingly.

Technical Assistance

JMA contributes in various ways to the improvement of disaster mitigation systems in other countries and to the establishment of international tsunami warning systems.

Bilateral Assistance

In conjunction with the Japan International Cooperation Agency (JICA) and other bodies, JMA hosts trainees from other countries at its offices and dispatches experts to overseas organizations based on its experience of earthquake/tsunami early-detection and information provision.

For countries and regions seeking to strengthen their tsunami warning capabilities, JMA provides technical support on various matters ranging from observation and analysis of earthquakes and tsunamis to information provision and disaster mitigation measures. Since the Indian Ocean Tsunami of 2004, JMA has received numerous support requests and provided technical assistance to related parties in Indonesia, Maldives, Myanmar, Turkey, Chile, the Philippines, El Salvador, Ecuador, Nicaragua and Vanuatu.

Multilateral Assistance

JMA contributes to the establishment of tsunami warning systems in various regions of the world through international conferences, workshops and the like within UNESCO/IOC framework. For instance, NWPTAC contributes to annual biennial Exercise Pacific Wave (PacWave) efforts by assisting with the production of exercise scenarios, manuals and products so that the countries concerned can conduct their own tsunami warning exercises.

JMA website

This page details useful functions and search methods on the JMA website, which was updated in February 2021.

Real-time disaster prevention information

Current Warnings/Advisories is displayed with icons and color-coding for at-a-glance determination of risk levels.

Select prefecture / municipality

Users can switch between nationwide, prefectural and municipal display and specify areas for Warning/Advisory information.

JMA sends various information through SNS as well as the website.

Promote safety awareness

How to interpret meteorological information

In the event of a disaster

Broadcast live of emergency press conference

Press releases

Event information

How to interpret disaster mitigation information

Promote awareness of disaster mitigation

In the event of a disaster

Information on current situations and future outlooks

Notes on disaster prevention

Details of press conferences
Protect yourself from Earthquake

Earthquake Readiness

Earthquakes strike out of the blue. Get to know your surroundings and evacuation routes, both indoors and outdoors, to prepare for tremors so that you can protect yourself.

✓ Stock provisions and other necessary items
Have a store of water and food, and keep an emergency kit.

✓ Secure a Safe Space
Create a “Safe Space” in your home where nothing can fall, topple over or move.

✓ Check for surrounding hazards
Check for hazardous areas and materials along commonly taken routes.
Rainfall may trigger landslides on and around soft ground or terrain loosened by earthquakes.

✓ Stabilize furniture
Secure furniture appropriately and consider placement to ensure an evacuation route if the securement fails.

✓ Check for surrounding hazards
Check for hazardous areas and materials along commonly taken routes.

✓ Drill!
Can you really protect yourself in emergency? Take part in drills to learn calm self-protect techniques.

✓ Establish methods of contact
Plan post-earthquake meet-up points and communications with family members.

If you feel shaking...

Stay calm and Secure your safety!

If you see/hear an EEW...

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

in Elevator
✓ Evacuate to “Safe Space”
✓ Stop the elevator at the nearest floor and get off immediately

on Bus or Train
✓ Protect your head and shelter under a table
✓ Do NOT rush outside
✓ Prioritize self-protection over firefighting

Protect yourself from Tsunami

Learn About Tsunami

Tsunami form as a result of sea wave propagation caused by uplift or sedimentation of the seafloor due to an earthquake.

❖ Escalation: As a tsunami approaches the coast and the sea becomes shallower, it grows much higher. Heights may exceed estimates in some regions due to coastal topography characteristics and other factors.

❖ Speed: If you see a tsunami, it’s already too late to evacuate.

❖ Power: Even knee-high tsunamis can wash people away.

❖ Recurrence: Tsunami can hit repeatedly due to reflection and refraction. Later waves may be higher.

❖ Duration: It may be several hours before the largest waves are recorded as tsunami-related sea level changes are observed.

❖ Precursor variety: Tsunami may be preceded by an ebb tide or a rising tide, the assumption of a preceding ebb tide only may be a fatal error.

Tsunami Readiness

✓ Check tsunami hazard areas
Familiarize yourself with the locations of tsunami hazard areas around your home and school or workplace with local government tsunami hazard map and topographical characteristics.

✓ Check tsunami safety areas
Check where tsunami evacuation areas and tsunami evacuation buildings are. Consider evacuation routes with local residents. Have multiple evacuation spots and areas of higher ground in mind.

✓ Drill!
Take part in disaster mitigation drills such as walking along evacuation route.

Leave coastal areas and Go to higher ground!

If you feel a strong shaking at seaside...

Be careful even during Advisory status
❖ Bathing or fishing in coastal areas even during a Tsunami Advisory is hazardous. Move away from the water and leave coastal areas immediately.

If you feel long-lasting slow shaking...

 Remain on alert until Warnings are lifted
Since tsunamis may strike repeatedly, remain on alert and keep evacuating until a Tsunami Warning/Advisory is lifted.
Never return to a coastal area while a Tsunami Warning is in effect.

If you see or hear a Tsunami Warning...

Be careful even during Advisory status
❖ Bathing or fishing in coastal areas even during a Tsunami Advisory is hazardous. Move away from the water and leave coastal areas immediately.

Get accurate information
✓ Accurate information can come from TV, radio, announcement vehicles, radio broadcast systems and the Internet.

Tsunami evacuation flag
❖ This red and white checkered flag indicates that Tsunami Warning/Advisory information has been issued. Evacuate as soon as possible.

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