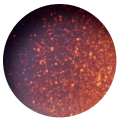
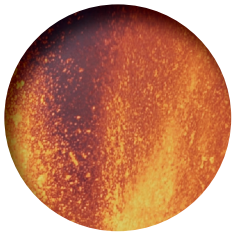




Earthquake · Tsunami · Volcano
Recent Progress & Challenges of the KMA

Volcano
Earthquake
Tsunami

Korea Meteorological Administration


VOLCANO
EARTHQUAKE
テレトラック
MIYAKO
TSUNAMI

Volcano
Earthquake
Tsunami

“ The Korea Meteorological Administration Earthquake and Volcano Bureau is advancing with the purpose of a more rapid and precise information dissemination to provide safety to Korea amid disasters such as earthquake·tsunami·volcano.”

After the 12th September 2016 earthquake in Gyeongju, people's concern and anxiety regarding earthquakes have increased.

Earthquakes, which tend to happen unpredictably, require preparation beforehand and prompt response.

Since the KMA first started observing earthquakes in 1905 and issued earthquake alerts from 1978, it has never stopped protecting the life and property of people.

In addition, based on the continuous international research and technical exchange and cooperation, earthquake·tsunami·volcano observation and analysis ability has been developed.

Regarding natural disasters such as unpredictable earthquake·tsunami·volcano,

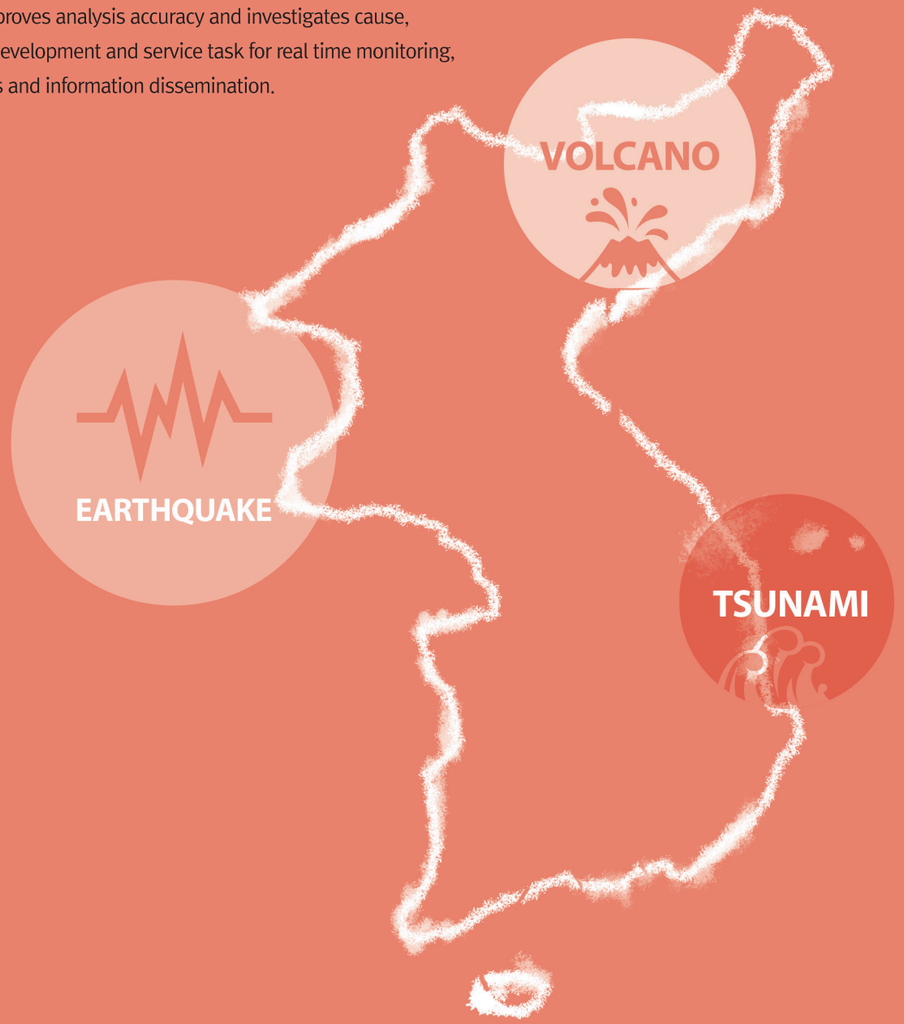
The KMA is providing precise and swift observations and alerts, helping with precise understanding of the people regarding such phenomena.

The KMA consistently analyzes the past, observes the present, prepares the future for the safety of Korea.

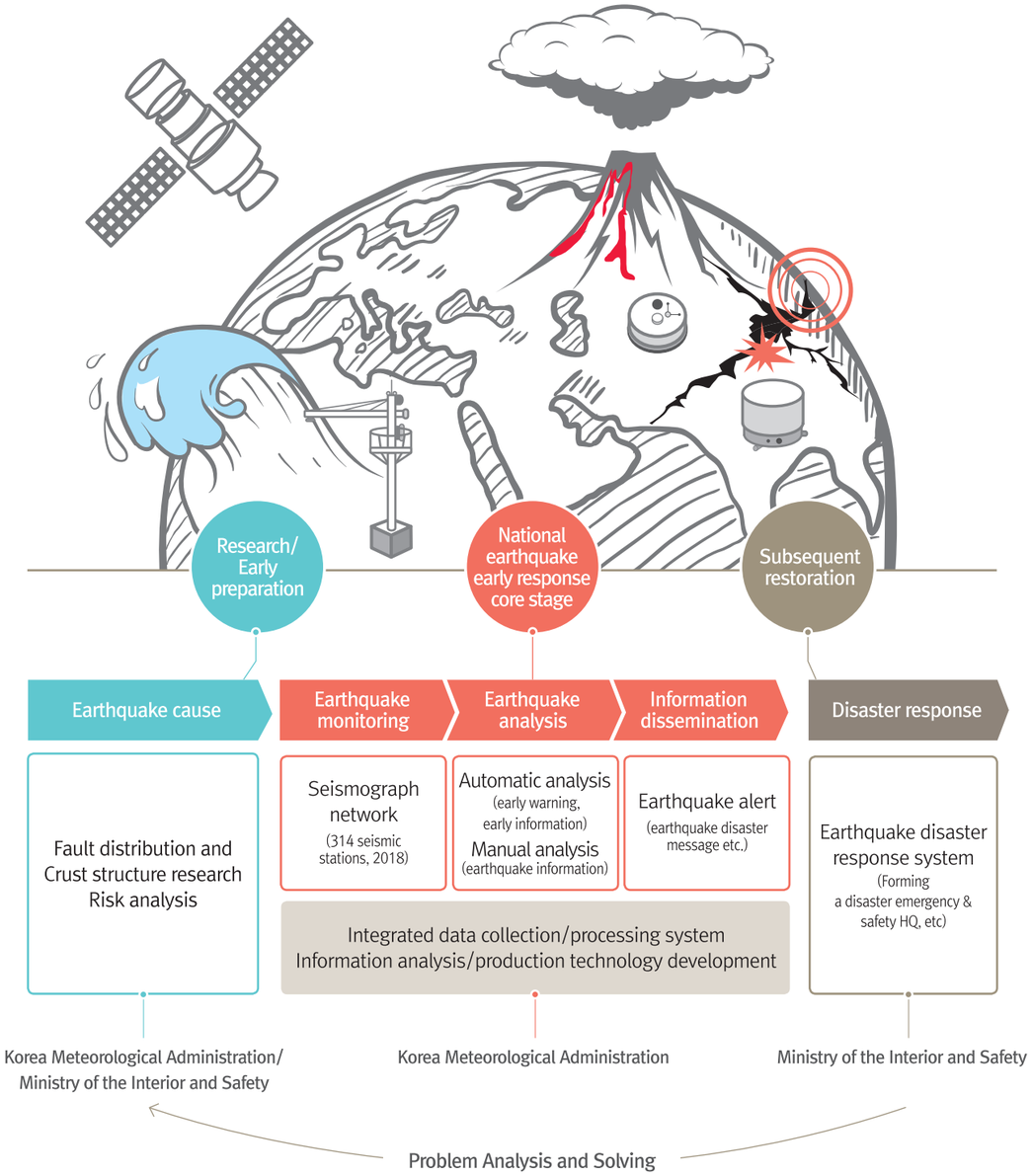
KOREA METEOROLOGICAL ADMINISTRATION EARTHQUAKE AND VOLCANO BUREAU

"Korea Meteorological Administration, which monitors·analyzes·alerts in real time the earthquake·tsunami·volcano occurring both domestically and abroad"

The KMA, which is a national organization that overlooks the core tasks within the rapid national response system regarding earthquake·tsunami·volcano, is executing R&D that improves analysis accuracy and investigates cause, policy development and service task for real time monitoring, analysis and information dissemination.



National Earthquake Task & Performance System



1st Earthquake·Tsunami·Volcano strategic plan

Mission

Protect life and property from disaster due to earthquake·tsunami·volcano.

Vision

Make society prepared for earthquake disaster through fast information dissemination for prompt decision making.

Shortening of earthquake early warning announcement time
50secs('16) ⇒ 7~25secs(at the end of 2018)

Earthquake·Tsunami·Volcano Task Future Plan

Strategy	Ⅰ Construct optimal seismograph network	Ⅱ Establish integrated information management system	Ⅲ Achieve advancement of analysis technology	Ⅳ Implement prompt information dissemination and its application	Ⅴ Develop a leading technical foundation for the future
Practice Direction	• Early construction of earthquake early warning observation network • Expand real time sharing of domestic observation data • Secure observation data cooperation system of surrounding countries	• Establish standard for observation facility, observation environment and observation equipment • Expand information sharing and utilization	• Performance improvement for rapid earthquake early warning • Provide earthquake intensity and its impact • Improve analysis technique and develop value-added information	• Diversify information dissemination media • Develop earthquake impact information especially for national main infrastructure such as nuclear power plant	• Strengthen education and training system for competence development • Implement efficient R&D investment and management policy to resolve current issues
5 Years Later	• Increase Seismograph network density : 22km('16) ⇒ 18km('18) • Expand earthquake early detection (Within 5 seconds) possible area * Area ratio based on inland : 20%('16) ⇒ 90%('21)	• Establish quality management system establishment such as observation environment, equipment, data • Expand sharing and application of domestic related institutions' earthquake data – Collection rate : 51%('16) ⇒ 90%('21) – Data use rate for EEW : 40%('16) ⇒ 70%('21)	• Shorten of earthquake early warning announcement time : 50 secs ('16) ⇒ 7~25 secs ('18) • Shift the paradigm earthquake information service : : magnitude based ('16) ⇒ intensity based ('21) • Expand of earthquake analysis information type : 3 ('16) ⇒ 10 ('21)	• Diversification of dissemination media : 7 ('16) ⇒ 12 ('19) • Expansion of direct information to the public : 82%('16) ⇒ 95%('21)	• Strengthen internal personnel training system and expand exterior expert pool • Develop core original technology development such as next generation earthquake early analysis technology development appropriate for the Korean Peninsula

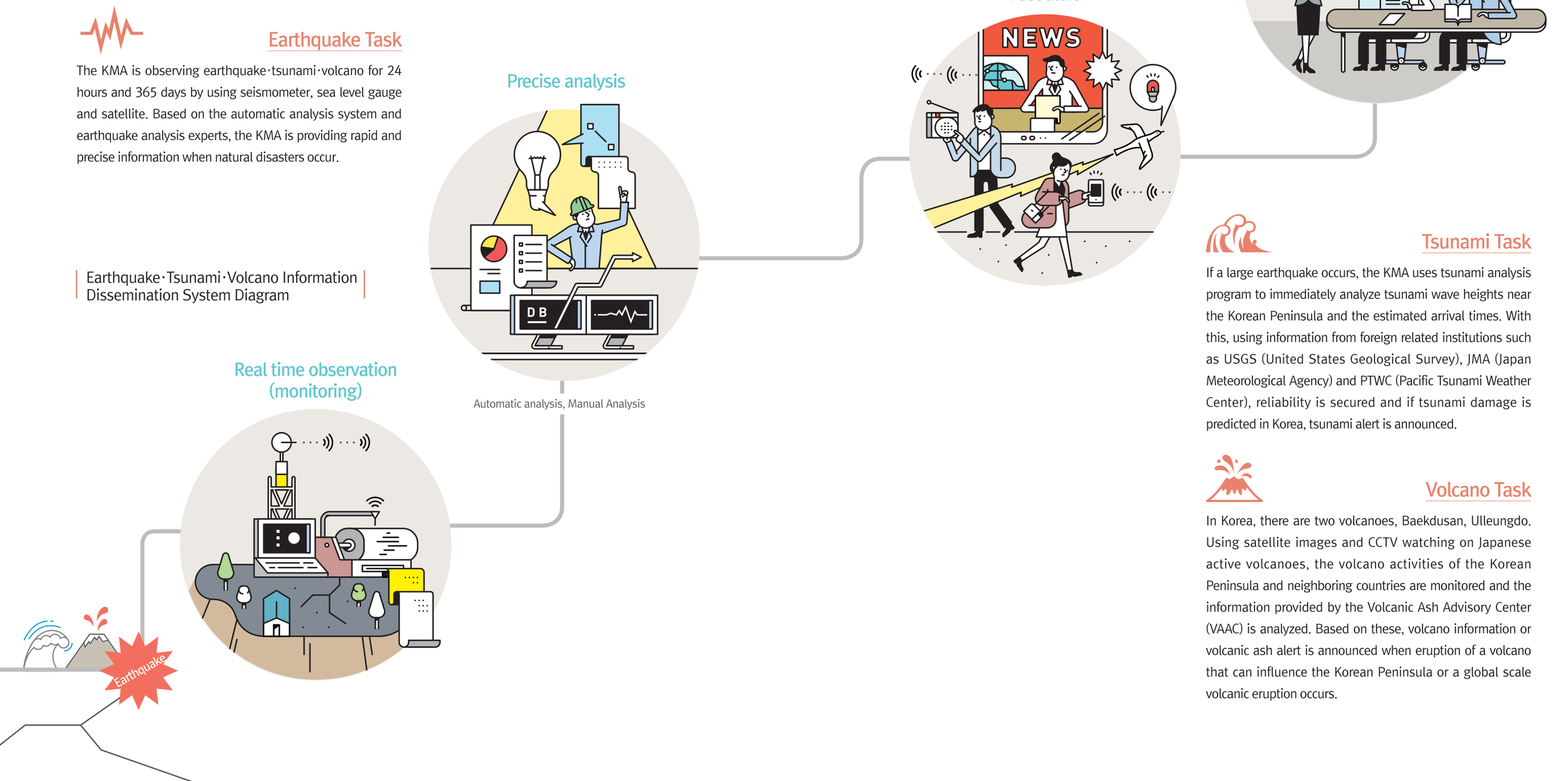
Earthquake·Tsunami·Volcano Tasks

" Timely information dissemination is essential for earthquake·tsunami·volcano that is hard to predict!"

Earthquake Task

The KMA is observing earthquake·tsunami·volcano for 24 hours and 365 days by using seismometer, sea level gauge and satellite. Based on the automatic analysis system and earthquake analysis experts, the KMA is providing rapid and precise information when natural disasters occur.

Earthquake·Tsunami·Volcano Information Dissemination System Diagram



Tsunami Task

If a large earthquake occurs, the KMA uses tsunami analysis program to immediately analyze tsunami wave heights near the Korean Peninsula and the estimated arrival times. With this, using information from foreign related institutions such as USGS (United States Geological Survey), JMA (Japan Meteorological Agency) and PTWC (Pacific Tsunami Weather Center), reliability is secured and if tsunami damage is predicted in Korea, tsunami alert is announced.

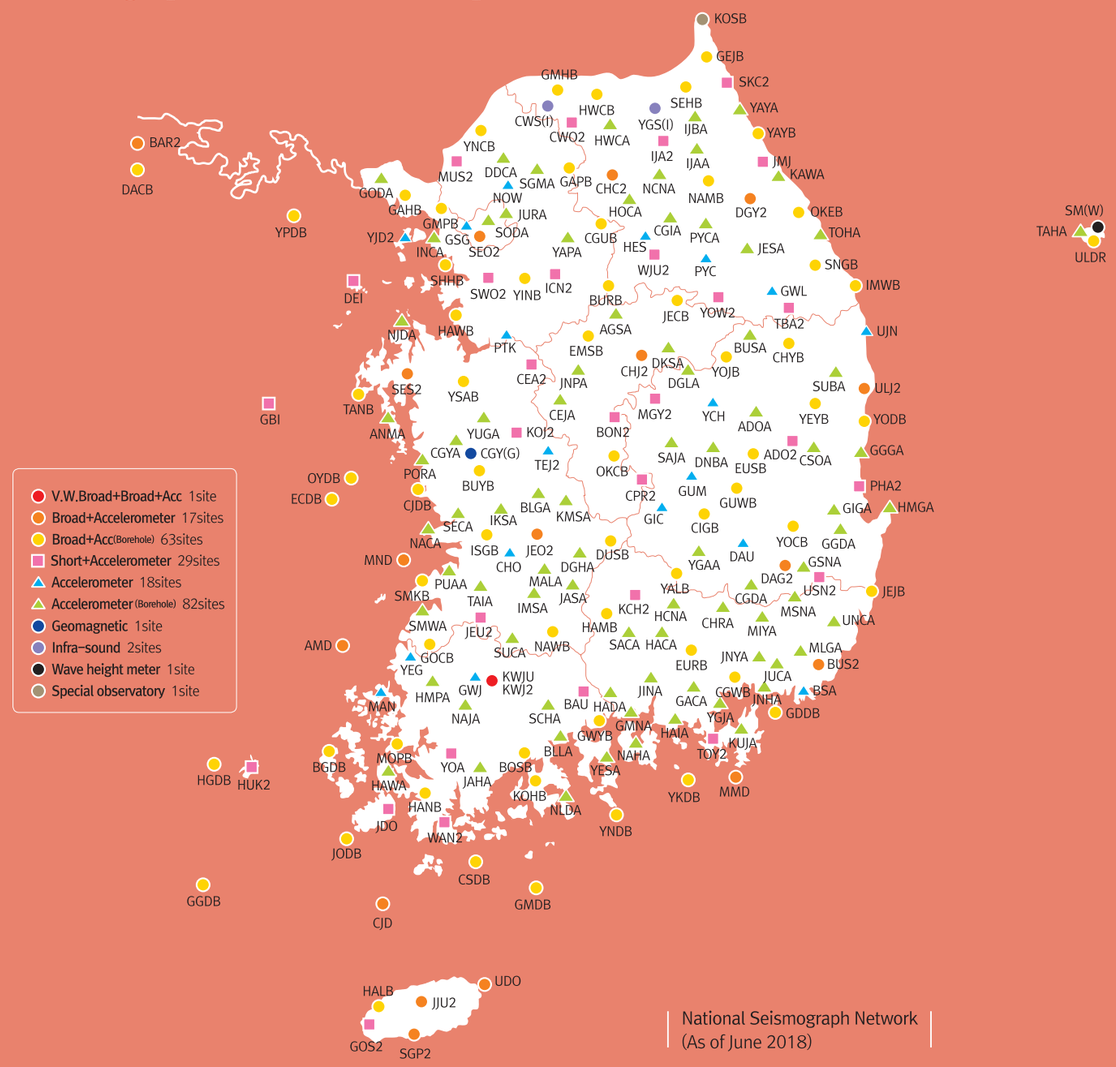
Volcano Task

In Korea, there are two volcanoes, Baekdusan, Ulleungdo. Using satellite images and CCTV watching on Japanese active volcanoes, the volcano activities of the Korean Peninsula and neighboring countries are monitored and the information provided by the Volcanic Ash Advisory Center (VAAC) is analyzed. Based on these, volcano information or volcanic ash alert is announced when eruption of a volcano that can influence the Korean Peninsula or a global scale volcanic eruption occurs.

Earthquake Task

Observation of Earthquake

"Sharing and application of seismic big data and establishing dense seismograph network for a more precise observation"



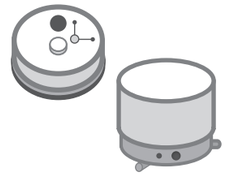
- V.W.Broad+Broad+Acc 1site
- Broad+Accelerometer 17sites
- Broad+Acc(Borehole) 63sites
- Short+Accelerometer 29sites
- Accelerometer 18sites
- Accelerometer(Borehole) 82sites
- Geomagnetic 1site
- Infra-sound 2sites
- Wave height meter 1site
- Special observatory 1site

National Seismograph Network
(As of June 2018)

National Seismograph Network

Currently, (As of June 2018) the KMA is collecting seismic data of from 261 seismic stations (211 of KMA, 50 of domestic related institutions) and is expanding up to 314 seismic stations by 2018 for a more precise observation.

Seismic Instrument



As a seismic instrument to analyze the magnitude and location of the earthquake, there are two types of the seismic sensor which are mutually supplementary. The seismic sensor is classified into a seismometer to measure the seismic velocity of the ground and accelerometer to measure the intensity.

Current State of Seismic Network (As of June 2018)

Name of Institution \ Type of seismometer	Seismometer				Accelerometer		Total
	Ultra Broadband	Broadband		Short Period	Surface Type	Borehole Type	
		Surface Type	Borehole Type				
KMA	1	17	64	29	18	82	211

National Observation Data Quality Management and Performance Test System

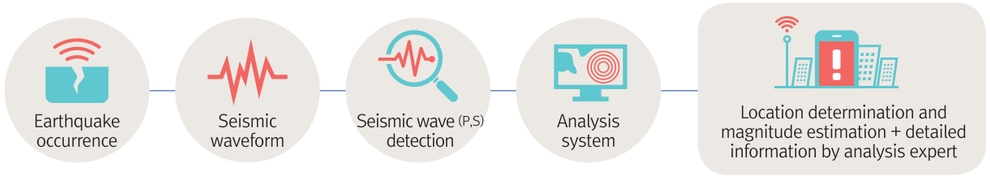
For the advancement of earthquake information such as earthquake early warning and intensity information service, an accuracy improvement of earthquake information through high quality seismic data production and quality management are essential. Along with the seismic instrument directly installed-managed, the KMA is seeking to increase reliability of earthquake information through utilization of domestic related institutions' seismic data. The KMA is pursuing standardization of observation facility and observation environment (2019~2021) and pursuing the construction of seismic data utilization system at national level. Through this, it is striving to develop new alert system (on-site warning) and advancement of earthquake early warning.

As the first step, the implementation of performance test system for the seismic instrument is being pursued. The KMA is establishing the quality management of seismic data by preparing the systemization of standard performance test according to the observation target and purpose of seismic instrument (2018~2020). The appropriate performance test items for each sensor will be selected. Then standard and process for each item will be developed. In 2019, it will select performance test items focusing on the main factors of seismic instrument and first examine the possible factors among these items.

Analysis of Earthquake

"For unpredictable earthquake, analyze rapidly and precisely"

Earthquake Analysis System



Automatic Analysis and Manual Analysis

Automatic analysis automatically analyze through earthquake early warning system using rapid seismic wave(P wave)
– Prompt information : earthquake early warning and earthquake early information

Manual analysis analyze overall seismic data of many seismic stations in detail by earthquake analysis experts
– Detailed information : earthquake information

	Automatic analysis				Manual analysis			
Classification	Prompt Information				Detailed Information			
	Earthquake early warning		Earthquake early information		Earthquake information		Abroad earthquake information	
Announcement Standard	Domestic Earthquake	5.0 or more	Domestic Earthquake	(In land) 3.5 or more, less than 5.0	Domestic Earthquake	2.0 or more	Within area	(In land) 5.0 or more
								(Seas) 5.5 or more
	Abroad Earthquake*	5.0 or more		(Seas) 4.0 or more, less than 5.0			Outside area	(In land) 6.0 or more
								(Seas) 7.0 or more
Contents	Origin time, Estimated epicenter, Estimated magnitude, Estimated intensity				Origin time, Epicenter, Magnitude, Instrumental intensity, Focal depth		Origin time, Epicenter, Magnitude, Focal depth	
Manufacturing method	Earthquake early warning system				Analysis system		–	

* Execute early warning (trial) for earthquake in overseas country ('18.6 ~): In the event of anticipation of substantial effect of more than seismic intensity of IV in Korea even if an earthquake occurs overseas.

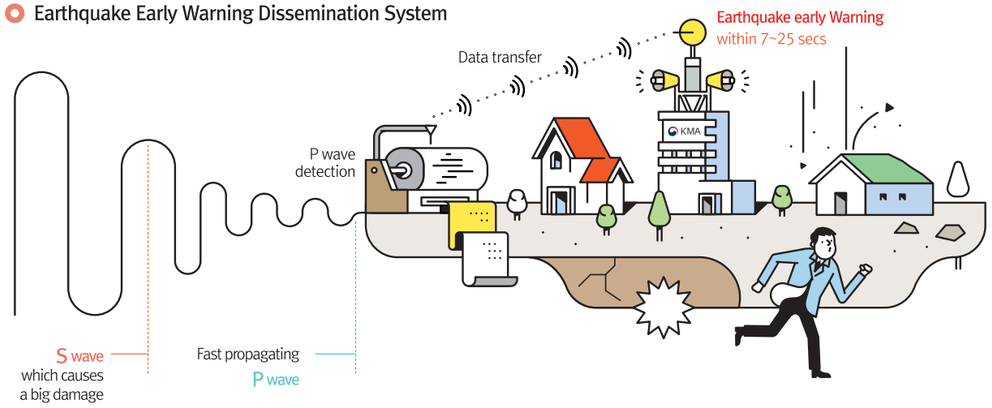
Earthquake Early Warning

"A lot of lives and properties are protected by providing prompt earthquake information"

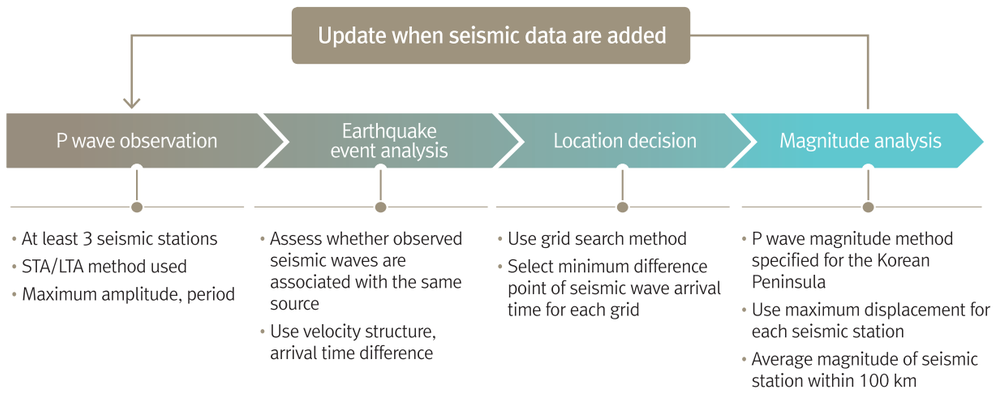
Earthquake Early Warning

By using a property that P wave propagates around 1.73 times faster than S wave, earthquake early warning detects P wave and notifies rapidly the earthquake occurrence and secures response time beforehand until S wave arrives. Regarding earthquake of magnitude 5.0 or more, it is currently providing information within about 15~25 seconds after observation (7~25 seconds at the end of 2018). However, for the rapid information provision, the announced earthquake early warning has uncertainty factor and the information may be changed after the earthquake early warning announcement through manual analysis (detailed information).

Earthquake Early Warning Dissemination System



Earthquake Early Warning Analysis Method



Domestic Earthquake Early Warning Announcement Case

In accordance with the article 14 (earthquake early warning system construction · management) of the Act on the Observation and Warning of Earthquakes, Tsunamis, and Volcanic Eruptions the KMA is providing an earthquake early warning service from January 2015. The first earthquake early warning was issued in July 2016 when the Ulsan offshore Earthquake occurred and 3 earthquakes of magnitude 5 or more occurred just in 2016. After observing earthquake, the KMA normally announced earthquake early warning within around 26~27 seconds and the Pohang Earthquake that occurred in November 2017 reduced the issuing time of the earthquake early warning by announcing 19 seconds after observing earthquake through the improvement of analysis technology.

Earthquake Early Warning Time Issuing Cases

	Occurrence Date	Magnitude	Main Current States (HH:MM:SS)			Note
			Occurrence	First Observation	Early Warning	
Ulsan offshore Earthquake	2016.07.05.	5.0	20:33:03	20:33:14	20:33:41	27 seconds after observation
9.12 Gyeongju Earthquake (foreshock)	2016.09.12.	5.1	19:44:32	19:44:35	19:45:03	27 seconds after observation
9.12 Gyeongju Earthquake (mainshock)		5.8	20:32:54	20:32:57	20:33:23	26 seconds after observation
Pohang Earthquake	2017.11.15.	5.4	14:29:31	14:29:34	14:29:53	19 seconds after observation

Tip

Uncertainty factor of earthquake analysis information

The earthquake analysis information can show difference according to velocity structure of earthquake occurrence region, performance difference of seismometers and seismic network density.

- Uncertainty of crust velocity structure where seismic wave propagates
- Uncertainty in each seismic station's analysis of initial travel time of seismic waves(P and S wave, etc.)
- Seismic network density and its distribution relative to earthquake occurrence region

Intensity Service

"Strengthen disaster prevention response by providing customized intensity information more relevant to each region"

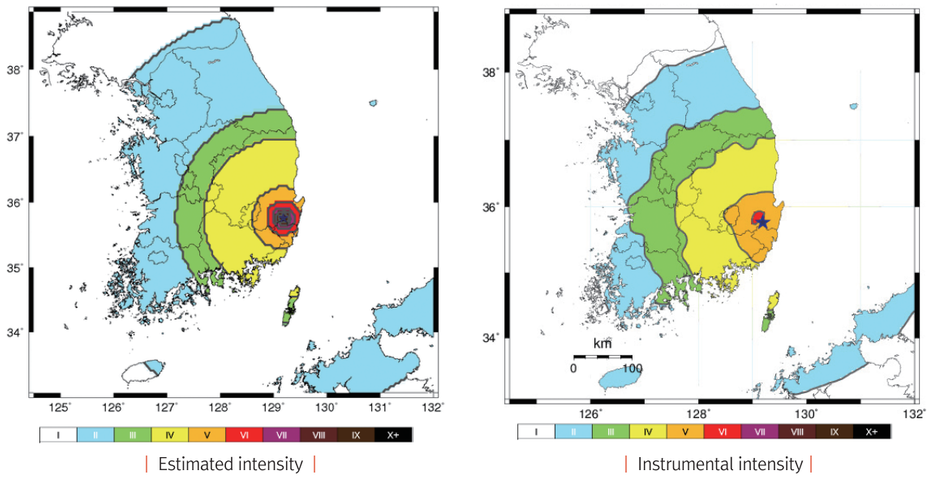
The intensity service is a service additionally providing estimated intensity and instrumental intensity added to the existing earthquake information (origin time, epicenter, magnitude etc.) Intensity information will be more relevant to effective earthquake risk response of local governments and individuals. The intensity service is currently being tested within the related institutions and will be provided to the public from the second half of 2018.

Estimated Intensity and Instrumental Intensity

① **Estimated intensity :** intensity estimated based on magnitude and distance
- As the seismic wave propagates from the epicenter, its energy is dissipated and its shaking strength gets smaller with distance. If the earthquake epicenter and magnitude are decided using seismic waves, the ground motion at each distance is estimated by using theoretical attenuation function and finally is classified according to the intensity scale.

② **Instrumental intensity :** intensity calculated by considering measured value of the accelerometer installed in each region and regional ground response property
- After the earthquake occurs, the seismic wave propagates and the maximum amplitude value recorded at the nationwide accelerometers is classified by intensity scale.

Estimated intensity and Instrumental intensity of 9.12 Gyeongju Earthquake (M 5.8)

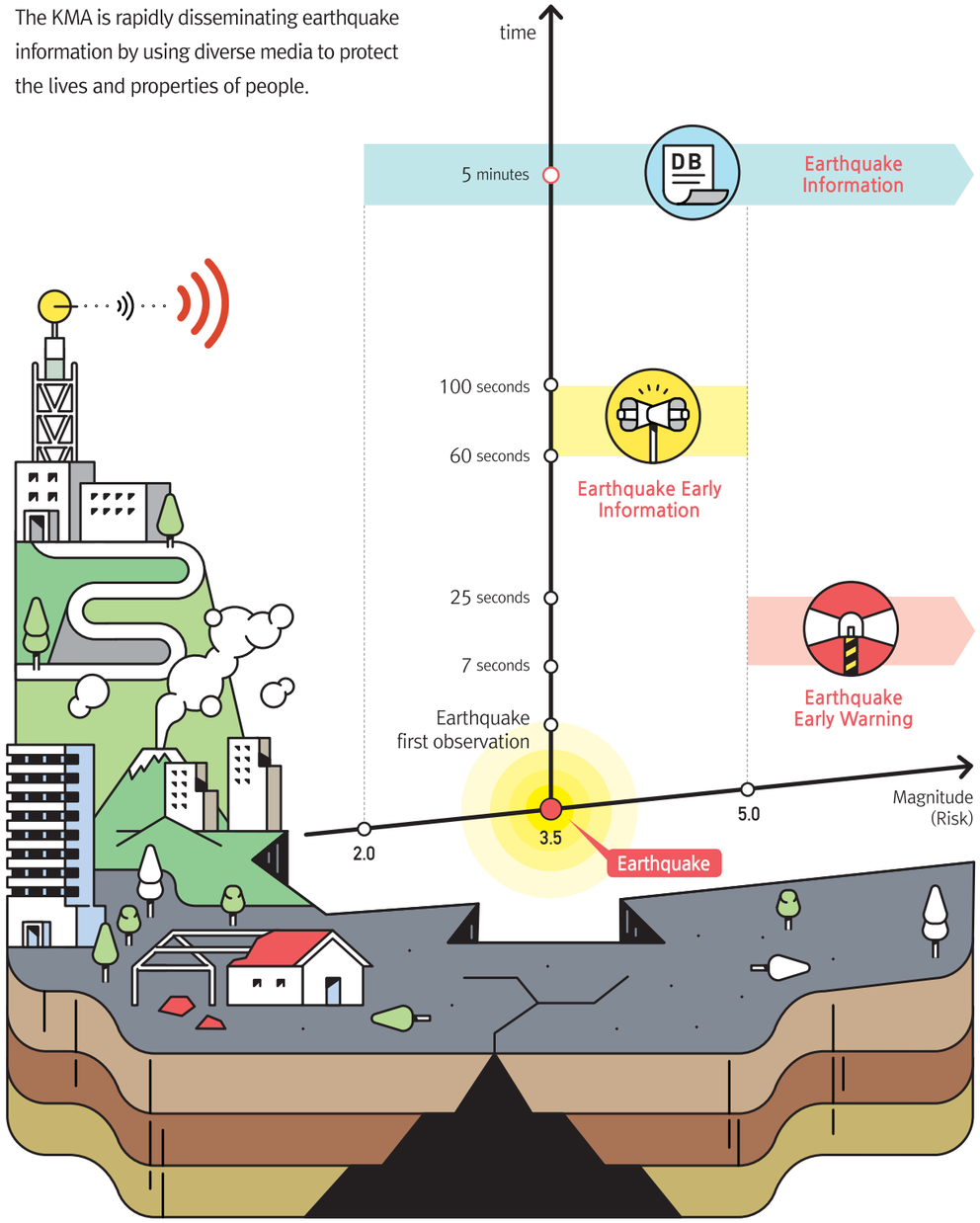


Estimated intensity | Instrumental intensity

Earthquake Alert Service

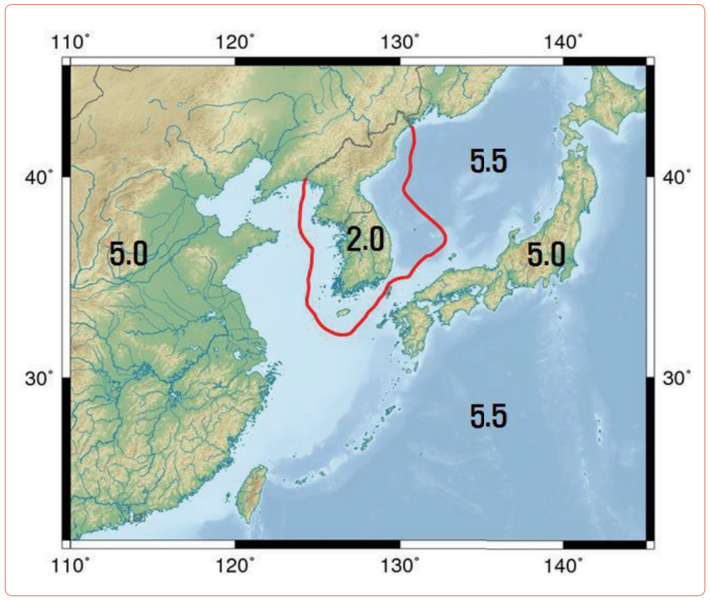
"Diverse channel application for earthquake information dissemination to minimize blind zone"

The KMA is rapidly disseminating earthquake information by using diverse media to protect the lives and properties of people.



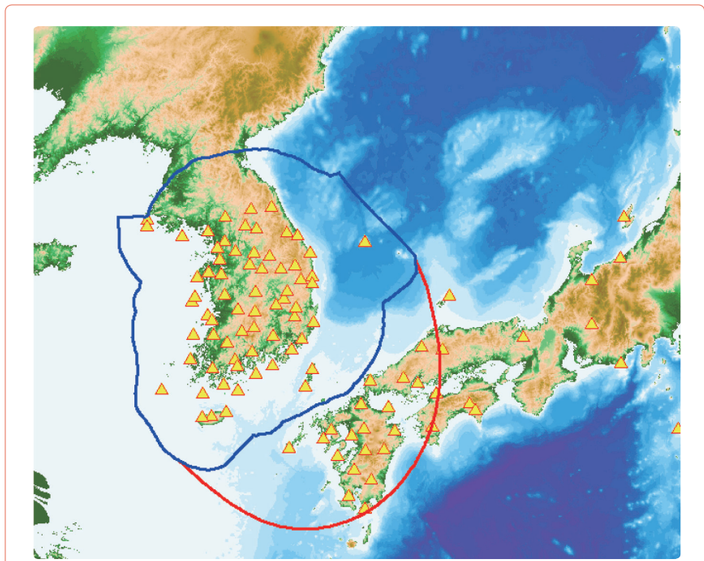
Earthquake and Tsunami Monitoring Area 〈Latitude 21°N~45°N, Longitude 110°E~145°E〉

※ The red line is domestic earthquake monitoring area and the number is the standard magnitude of earthquake alert

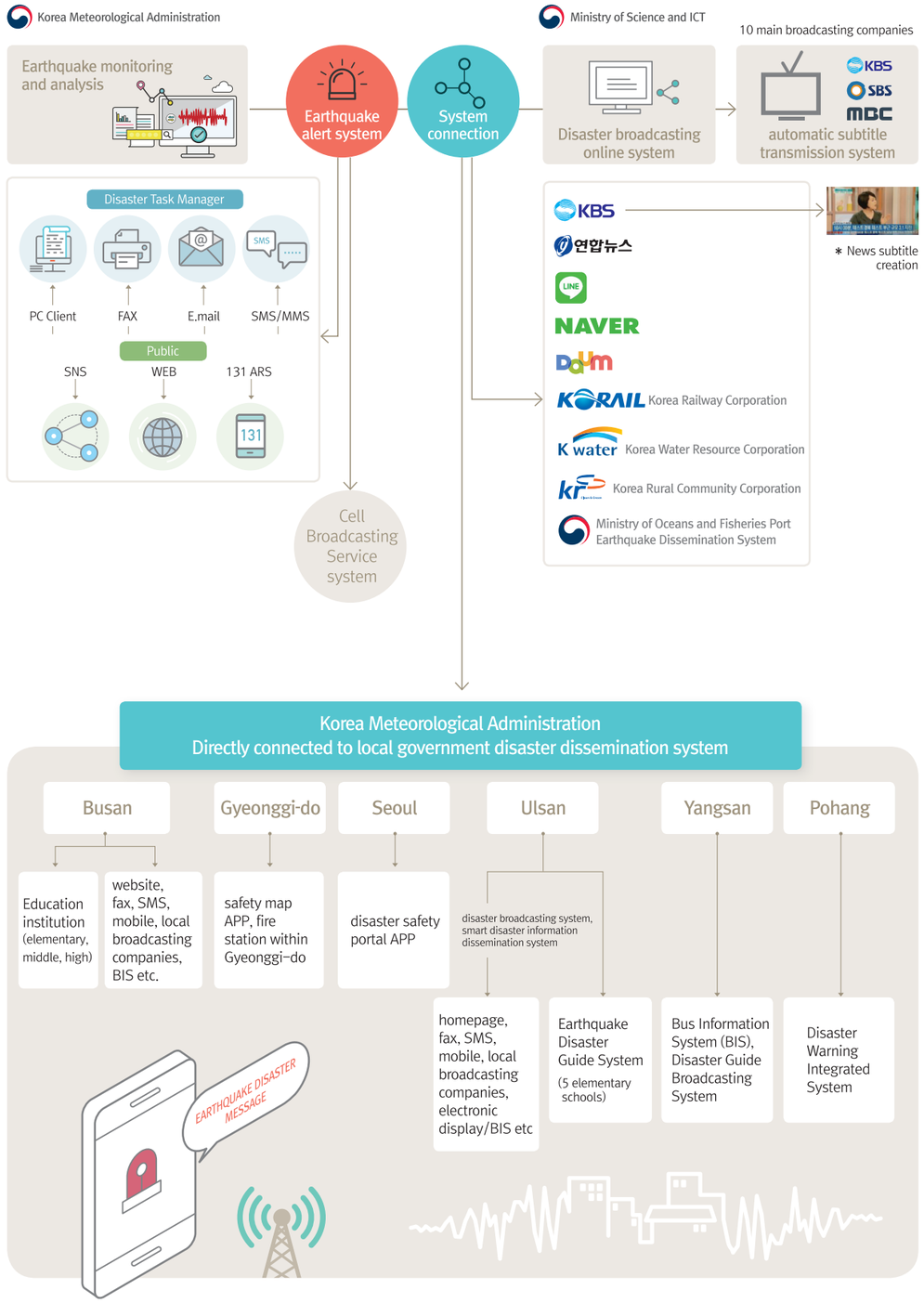


Earthquake Early Warning Area (As of June 2018)

— : Domestic Earthquake Early Warning Area
— : Abroad Earthquake Early Warning Area



Earthquake Information Dissemination System (As of June 2018)



Tip

Earthquake Cell Broadcasting Service

The Earthquake Cell Broadcasting Service (CBS) is sent for the relevant target area (metropolitan area unit) according to magnitude when earthquake of 3.0 or more has occurred. Since The KMA directly provided CBS from June 2018, a more rapid and precise earthquake information is transferred.

In addition, regarding earthquake with a magnitude of 6.0 or more that is expected to cause severe damage, it is classified as 'emergency disaster' and earthquake disaster message is forcefully sent. (Only available for 4G mobile phones which were released in Korea after 2016.)

If earthquake CBS message could not be received

- User of 3G phone, LTE phone produced before 2013, 2G phone produced before 2006
- Although it is CBS receipt possible phone, if it is located in an area where the user cannot receive message
- Although it is CBS receipt possible phone, if disaster message receipt function is OFF
- As the disaster message service (CBS) is sent in wave form, it may not be received according to the terminal. To prepare for this, the KMA is striving to disseminate earthquake information through diverse transfer media.

Transmission area according to earthquake magnitude

Magnitude		Transmission Area		Applicable Information
In land	Seas			
5.0 or more	5.0 or more	Nationwide		Earthquake early warning
4.0~ Less than 5.0	4.5~ Less than 5.0	Nationwide		Earthquake early information
3.5~ Less than 4.0	4.0~ Less than 4.5	Centered on epicenter	Radius of 50km metropolitan area	Earthquake early information
3.0~ Less than 3.5	3.5~ Less than 4.0		Radius of 35km metropolitan area	Earthquake information

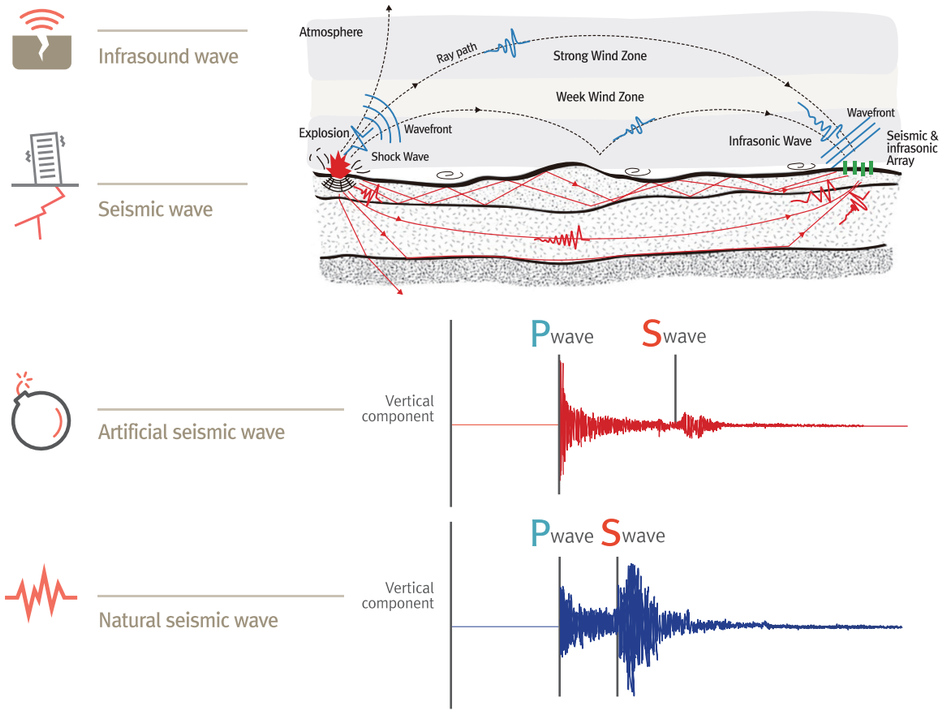
Artificial Earthquake

"An earthquake caused by artificial activity"

Unlike a natural earthquake occurring naturally within the crust, an artificial earthquake is an earthquake that has occurred due to human activity such as explosion or underground nuclear test. According to the Article 13 of the Act on the Observation and Warning of Earthquakes, Tsunamis and Volcanic Eruptions, the KMA monitors and analyzes artificial earthquake and its accompanying phenomenon.

Monitoring Artificial Earthquake

- **Seismic wave monitoring :** Since both artificial earthquake and natural earthquake can be known through seismic waves, these are observed using the same seismic sensor (seismometer, accelerometer). Unlike natural earthquakes, artificial earthquakes have bigger amplitudes of P wave than those of S wave
- **Infrasound wave monitoring :** Observing low frequency infrasound wave generated by explosions or nuclear tests.

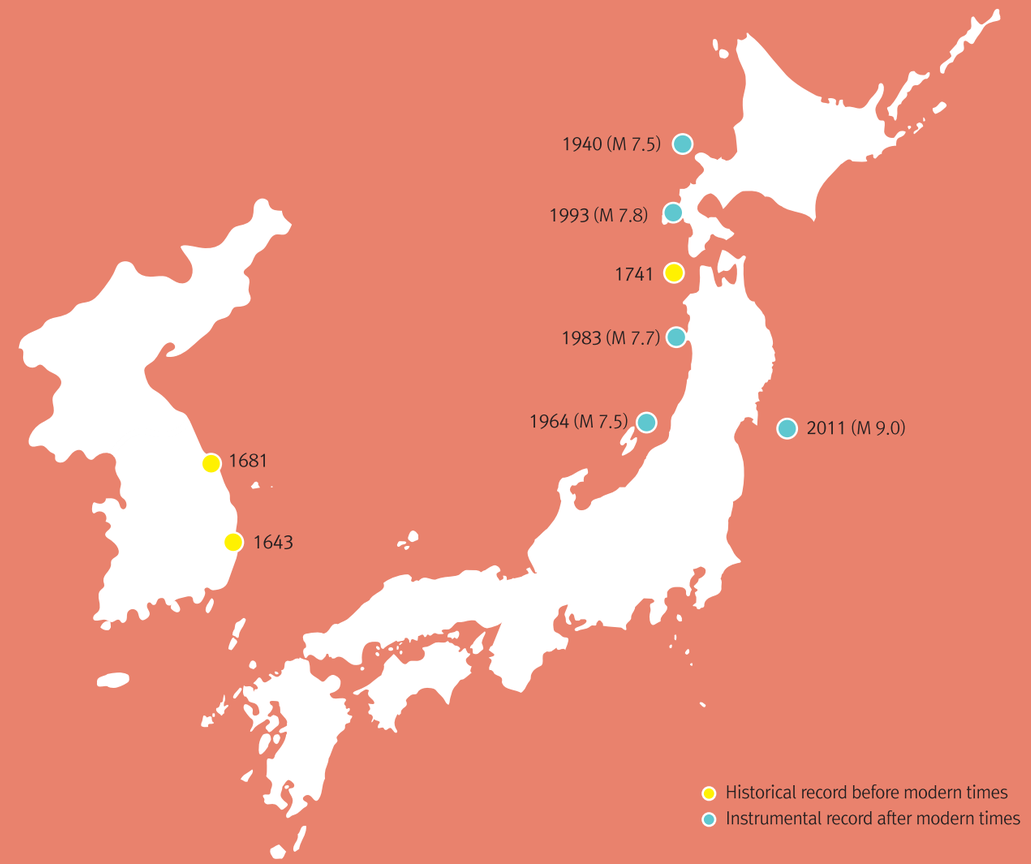


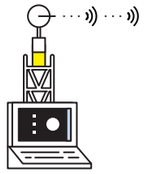
Tsunami Task

Tsunami

"We should be prepared for the disastrous tsunami generated by the submarine earthquakes"

Tsunami is waves with a very long wavelength, which is caused by the abrupt change of sea level height due to the seabed activity such as earthquake and submarine volcano explosion. There are several records of tsunami in Korea in premodern ages as well as modern age. Due to earthquakes occurring near the Western coasts of Japan, tsunami occurred 4 times in the Eastern coasts of Korea after the 1900s, implying that Korea could be prone to be affected by tsunami because the East Sea is very deep and there could be a big earthquake close to Japan.





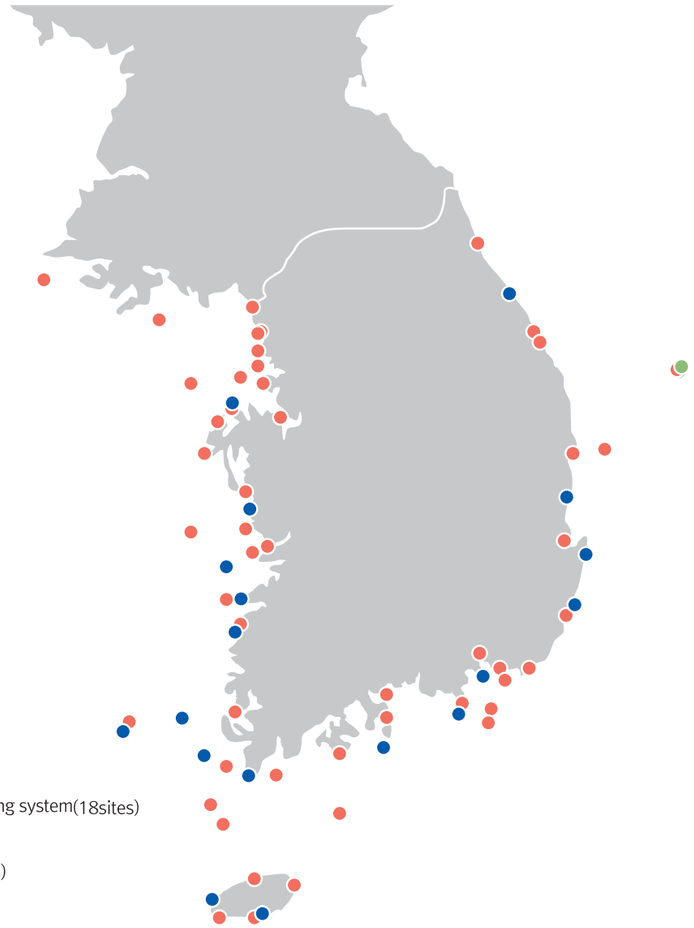
Tsunami wave gauge 1 site

Coastal disaster prevention observing system 18 sites

Tide gauges of Korea Hydrographic and Oceanographic Agency 50 sites

Tsunami Monitoring

The KMA is monitoring tsunami in real time by Ulleungdo tsunami wave gauge, coastal disaster prevention observing system and sea monitoring CCTV, as well as sharing tide gauges of Korea Hydrographic and Oceanographic Agency.

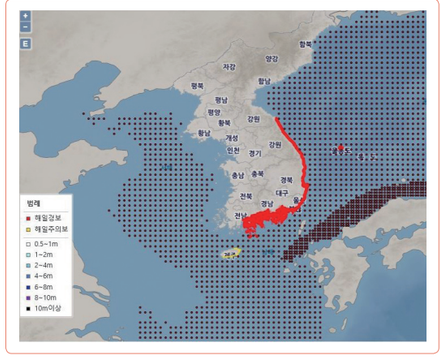


Tsunami Observation Network
(As of June 2018)

- Coastal disaster prevention observing system(18sites)
- Tide gauges of Korea Hydrographic and Oceanographic Agency(50sites)
- Tsunami wave gauge(1site)

Prediction of Tsunami

Assuming an occurrence of earthquake of magnitude 6.0~9.0 (0.2 interval) at around 6,000 epicenters under the seabed near the Korean Peninsula, the tsunami arrival time and wave height were simulated for 3,213 nationwide coastal points and archived in database(DB). When an earthquake of magnitude 6.0 or more occurs in the sea around the Korean Peninsula, the tsunami influence to the Korean Peninsula is estimated using the pre-archived DB and is disseminated if necessary. The information of the abroad related institution such as USGS (US Geological Survey), JMA (Japan Meteorological Agency) and PTWC (Pacific Tsunami Weather Center) is also utilized to provide more reliable tsunami information.



Example of Tsunami Scenario DB Display

Tsunami Alert (Advisory, Warning) Announcement Criteria

If a tsunami damage is expected in Korea after a large earthquake occurs in the seas near the Korean Peninsula, a tsunami advisory or warning is announced within 10 minutes. The tsunami alert (advisory, warning) includes information such as announcement time, concerned area, expected tsunami arrival time, wave height at the predefined main points along the coast of Korea and the earthquake parameters.

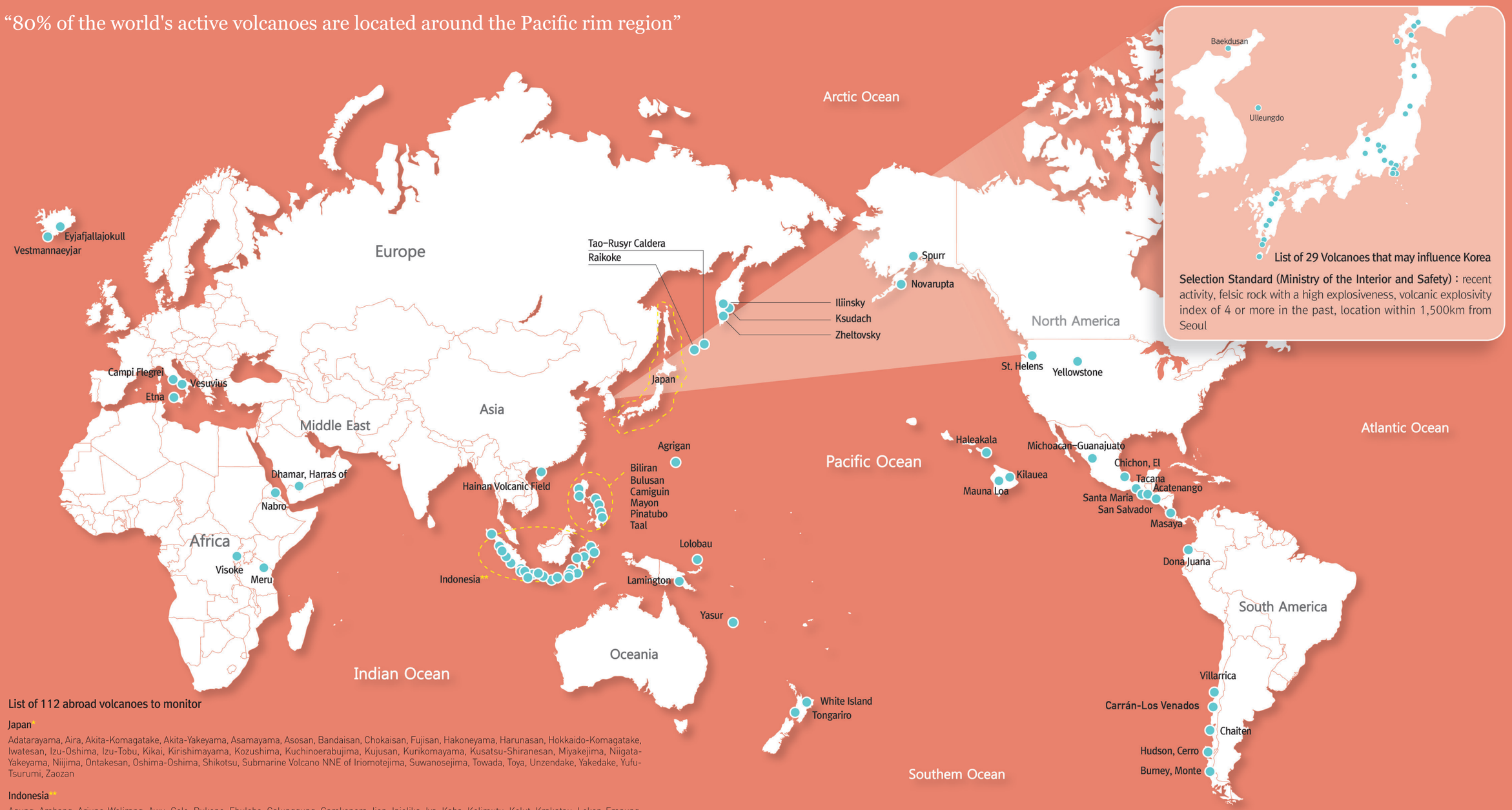
Tsunami Advisory	When tsunami height of 0.5m or more and less than 1.0m is expected in the Korean coasts due to submarine earthquake of magnitude 6.0 or more
Tsunami Warning	When tsunami height of 1.0m or more is expected in the Korean coasts due to submarine earthquake of magnitude 6.0 or more

* Even when it does not meet the alert announcement standard, if damage due to tsunami is expected, a tsunami advisory or warning may be issued.

Volcano Task

The mountain made by explosion or eruption of lava, pyroclastic and volcanic ash when the magma created in the earth interior comes out to the earth's surface is called ‘volcano’. In Korea, there are two volcanoes : Baekdusan, Ulleungdo. Of these, Baekdusan is estimated to have had a large scale eruption in the Goryeo Era around 946~947, which corresponds to the world's biggest Volcanic Explosivity Index(VEI) of 7. The last eruption was observed in 1903 and volcanic activity became active with large number of small volcanic earthquakes in 2002~2006. Baekdusan is evaluated to be an active volcano with a possibility of eruption in the future.

“80% of the world's active volcanoes are located around the Pacific rim region”



List of 29 Volcanoes that may influence Korea

Selection Standard (Ministry of the Interior and Safety) : recent activity, felsic rock with a high explosiveness, volcanic explosivity index of 4 or more in the past, location within 1,500km from Seoul

List of 112 abroad volcanoes to monitor

Japan*

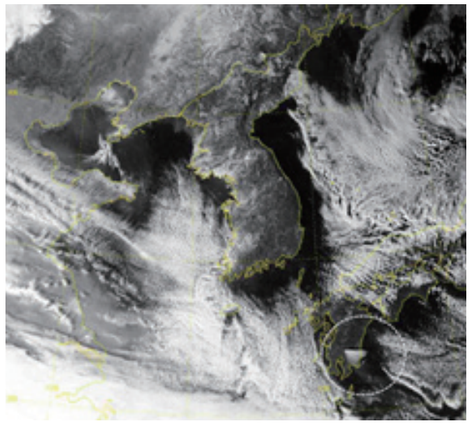
Adatarayama, Aira, Akita-Komagatake, Akita-Yakeyama, Asamayama, Asosan, Bandaisan, Chokaisan, Fujisan, Hakoneyama, Harunasan, Hokkaido-Komagatake, Iwatesan, Izu-Oshima, Izu-Tobu, Kikai, Kirishimayama, Kozushima, Kuchinoerabujima, Kujusan, Kurikomayama, Kusatsu-Shiranesan, Miyakejima, Niigata-Yakeyama, Niijima, Ontakesan, Oshima-Oshima, Shikotsu, Submarine Volcano NNE of Iriomotejima, Suwanosejima, Towada, Toya, Unzendake, Yakedake, Yufu-Tsurumi, Zaozan

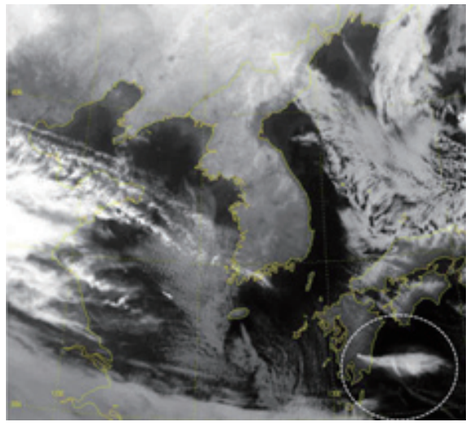
Indonesia**

Agung, Ambang, Arjuno-Welirang, Awu, Colo, Dukono, Ebulobo, Galunggung, Gamkonora, Ijen, Inielika, Iya, Kaba, Kelimutu, Kelut, Krakatau, Lokon-Empung, Merapi, Ranakah, Raung, Rinjani, Semeru, Sinabung, Soputan, Suoh, Tambora, Tandikat-Singgalang, Tangkubanparahu, Tengger Caldera

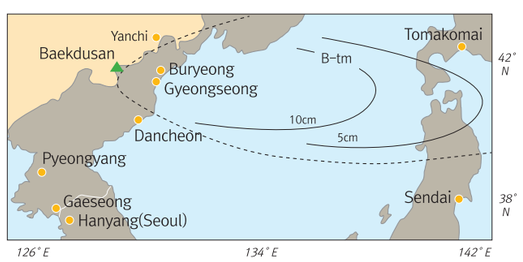
Monitoring and Prediction of Volcanic Activity

The volcanic activity of the Korean Peninsula and its neighboring countries is monitored using satellite image data of COMS. The location, time and plume of eruption, and the direction and speed of volcanic ash diffusion are analyzed using information provided by the Volcanic Ash Advisory Centres (VAAC) and atmosphere diffusion model. If there is a volcanic eruption in the Korean Peninsula's neighboring countries, the volcanic ash diffusion path is predicted after considering the ash plume height and atmosphere condition(wind direction, wind speed).

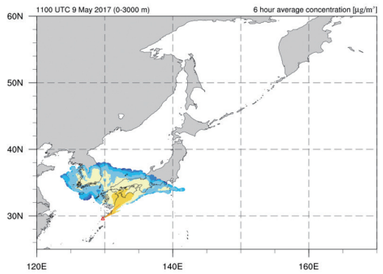




Satellite image data during Shinmoedake volcano eruption in Japan(Jan 26, 2011)



Volcanic ash diffusion due to Baekdusan eruption in 10th century

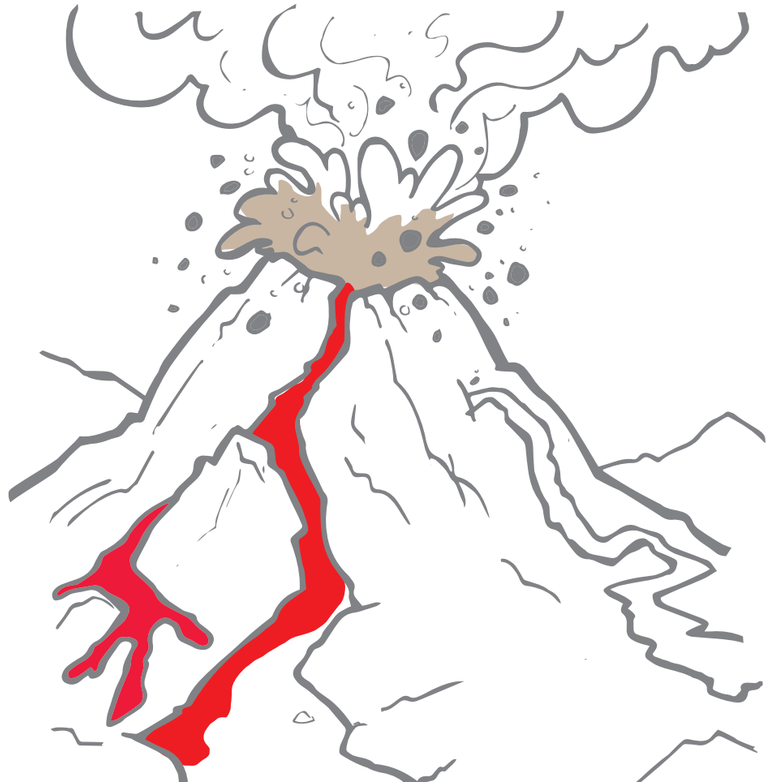


Volcanic ash simulation result during Suwanosejima volcano eruption in Japan (May 9, 2017)

Volcano Alert (Volcano Information, Volcanic Ash Alert) Announcement Criteria

The KMA announces volcano information, volcanic ash alert (volcanic ash advisory, volcanic ash warning) if volcanic eruption occurs.

Volcano Information	When domestic influence of volcanic eruption is expected When globally large volcanic eruption occurs and raises social interest
Volcanic Ash Advisory	When Korea is expected to be damaged by volcanic ash
Volcanic Ash Warning	When Korea is expected to be seriously damaged by volcanic ash



EARTHQUAKE · TSUNAMI · VOLCANO RESEARCH

"Advancement in monitoring, analysis and prediction technology regarding earthquake·tsunami·volcano for more accurate and tailored information"

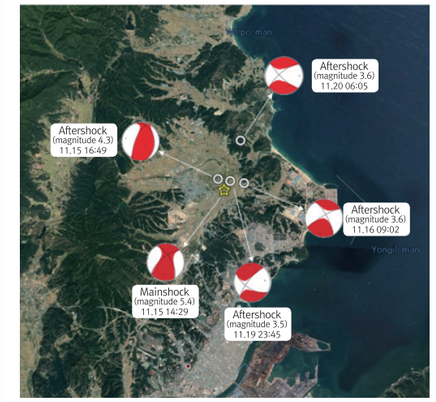
In order to provide more precisely and rapidly the earthquake·tsunami·volcano information, the KMA is conducting researches that develop and advance observation, analysis and prediction techniques. In order to produce precise earthquake information, we must manage the quality of the seismic data and need to advance the observation technology. For the accuracy of earthquake analysis results, diverse research regarding location and magnitude analysis method is required. Technology development to provide the analysed information in timely manner is also needed. Investigating the earthquake sources on the Korean Peninsula and understanding the earthquake occurrence environment are also important in preparing for an earthquake that may occur in the future. The Earthquake and Volcano Bureau in KMA is preparing a basis for the qualitative improvement of earthquake information through diverse research regarding earthquakes. As well as research on earthquake, tsunami, volcano and its related geophysical phenomena are investigated to provide more accurate and reliable analysis and prediction information.

EARTHQUAKE
TSUNAMI
VOLCANO

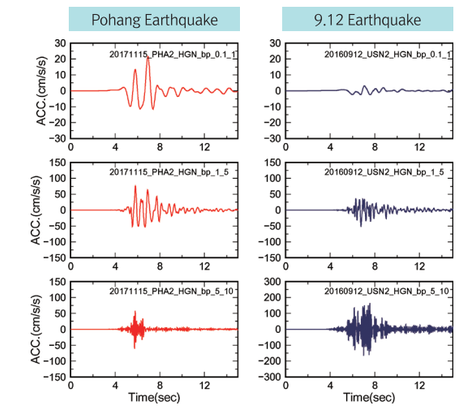
Earthquake

1. Research on Earthquake Characteristics and Earthquake Generation Environment in the Korean Peninsula

By analyzing the characteristics of main earthquakes such as the 2016 Gyeongju earthquake and 2017 Pohang earthquake, we can understand which type of earthquake may occur on the Korean Peninsula, which environment will cause it and which effects the earthquakes will raise. These understandings will lay the essential foundation for prediction and preparation for future earthquakes. In addition to research on characteristics of past earthquakes, a 'Development of integrated model of subsurface fault and velocity structure in Korean Peninsula' research has also been conducted to investigate the fault and velocity structure so that one can understand about the environment where the earthquake may occur and predict more precisely the ground motions during the earthquake.

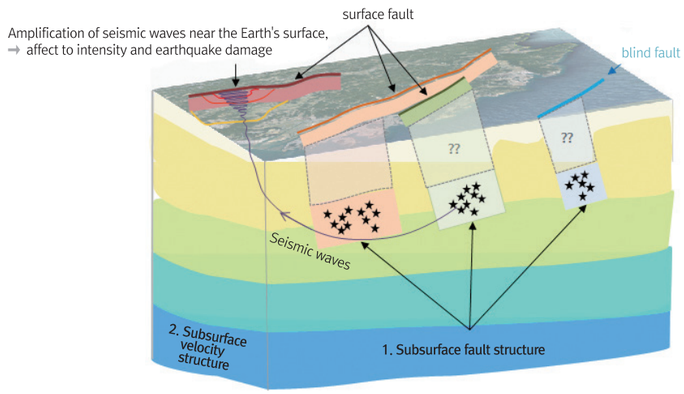


Fault Movement Characteristics of 2017 Pohang Earthquake



Comparison of Seismic Waves of Pohang and 9.12 Gyeongju Earthquakes depending on frequency band

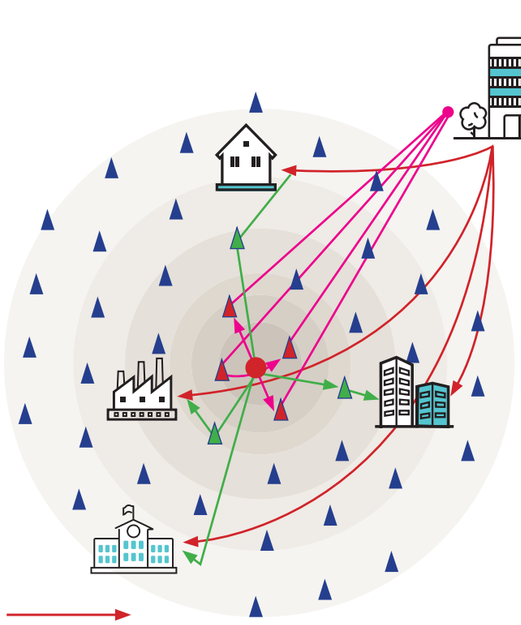
Schematic diagram on 'Development of integrated model of subsurface fault and velocity structure in Korean Peninsula'



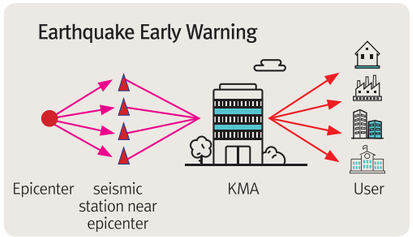
2. On-Site Warning Technology Development

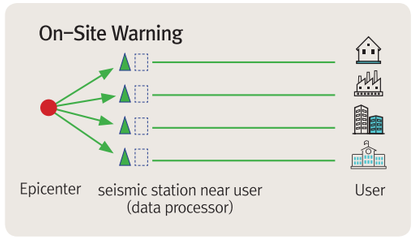
Even though the earthquake early warning is issued, there may be a region close to the epicenter, where the strong seismic wave already passed by before receiving earthquake warning message. This region is called the blind zone. The KMA is striving to shorten the issuing time of the earthquake early warning within 7~25 seconds using network warning method and to minimize the blind zone. The KMA is also developing on-site warning technology for mitigating the earthquake hazard of the national main infrastructure such as railways, nuclear power plant as well as the minimization of earthquake early warning blind zone.

* On-Site warning technology : Technology that issues earthquake information using only 2~3 seismic stations near the earthquake.



Earthquake Early Warning
On-Site Warning

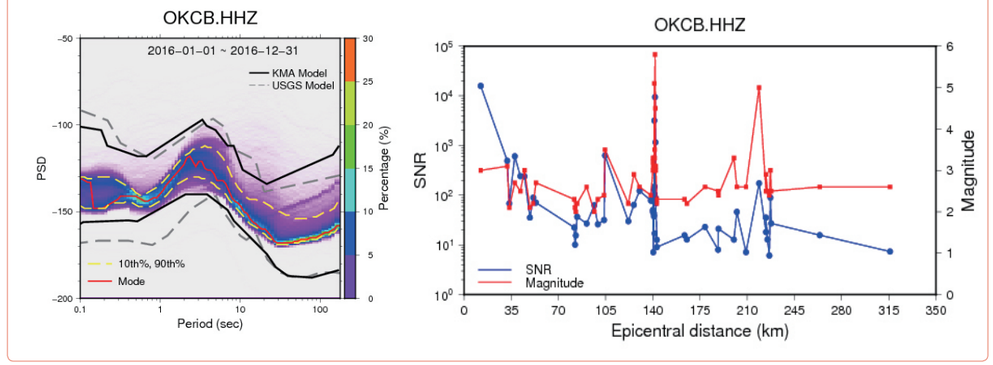




Classification	Earthquake Early Warning	On-Site Warning
Advantages	Minimizing uncertainty Reducing information providing time compared to existing method	Minimizing warning time
Disadvantages	Time delay as much as use of seismic stations Broad blind zone	Inceasing uncertainty Minimum blind zone

3. Seismic Data Quality Management Method Research

In order to maintain the quality of seismic data at the 261 (as of June 2018) nationwide seismic stations, diverse analysis technology is being developed and applied to observed data, such as analysis of background noise surrounding the seismic stations, seismic data collection rate, signal detection rate and signal to noise ratio.

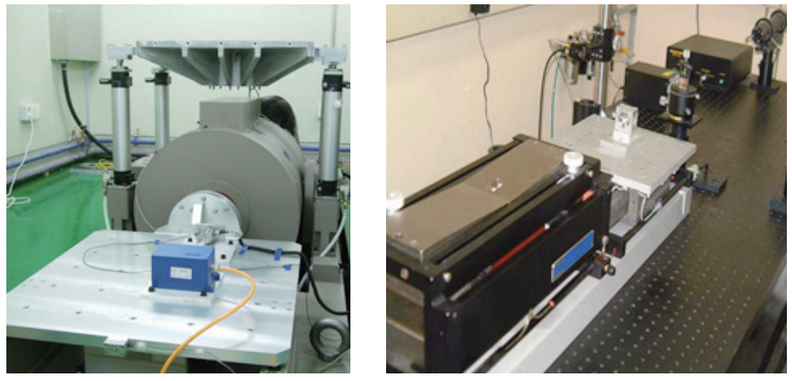


| Seismic station's background noise level in frequency domain and signal to noise ratio analysis result (example) |

4. Standard Research for Seismic Instrument Performance Test

The Performance test regarding seismic instrument has been enacted for sharing and application expansion of nationwide seismic data by securing seismic data accuracy and reliability. Based on this, a standard regarding performance test elements and verification methods, which have to secure traceability from the national standard, have been investigated (2017~2019) to supplement insufficient verification infrastructure and personnel.

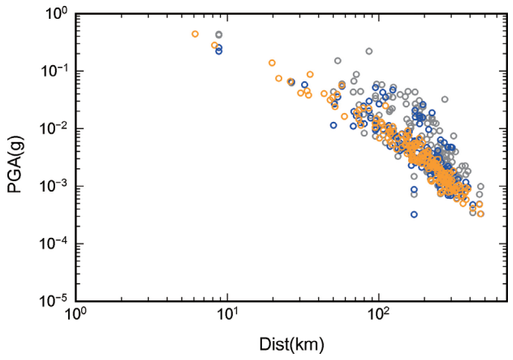
Especially, with regards to seismometer, the KMA establishes verification process for core elements that can represent the characteristics of instrumental performance such as sensitivity, frequency range and dynamic range.



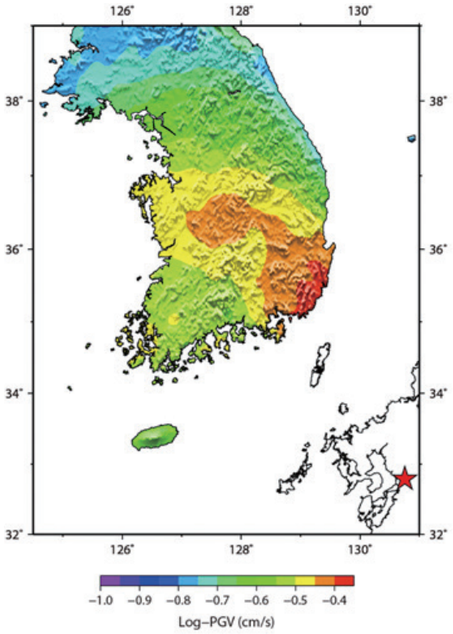
| Seismometer Performance Test Infrastructure (Horizontal Table and Shaker, Large(Left), Small(Right)) |

5. Intensity Information Service Advancement Technology Development

'Intensity', which indicates the degree of earthquake damage or the feeling by people, differs depending on magnitude, distance from the earthquake, and the underground conditions. Researches are carried out to analyze how much the ground motion attenuates by distance on the Korean Peninsula and to reflect different underground characteristics by region to the intensity calculation. In addition, a technology needed to provide intensity information due to large earthquakes in Japan is being developed.



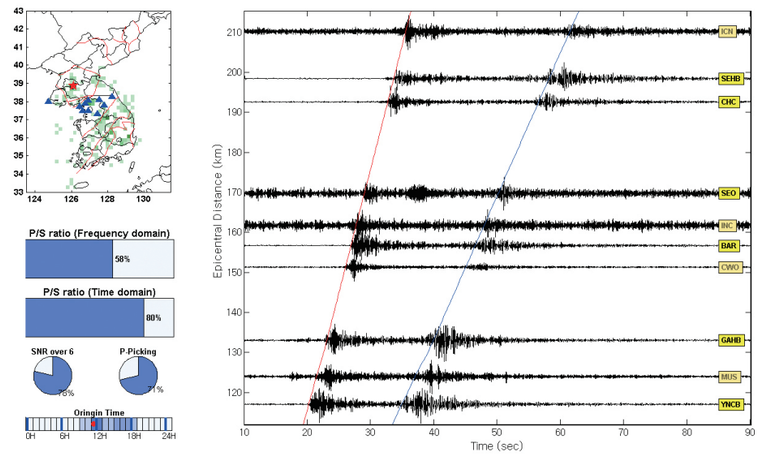
Attenuation Distribution of Peak Ground Acceleration by Distance



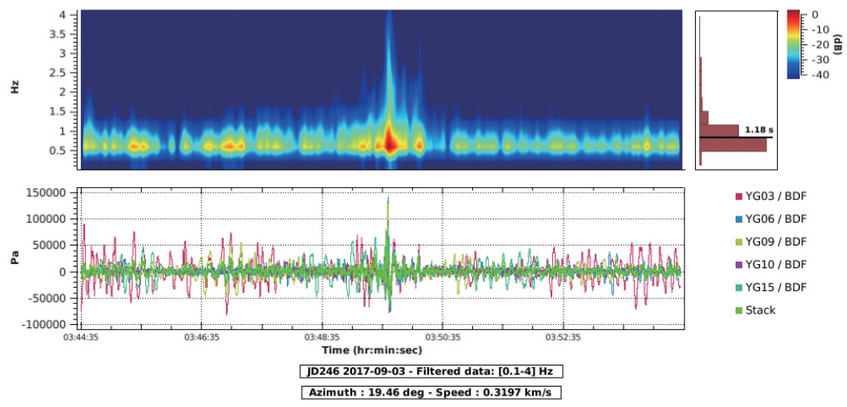
Intensity Estimation Technology Development Due to Japanese Earthquakes

6. Artificial Earthquake Discrimination Technology Development

The seismic signals due to artificial source such as blast are detected and such signals must be separated from natural earthquake signals. For this, a method to distinguish whether the signal being observed is similar to or different from the characteristics of the natural earthquake is being developed and applied. For example, although the amplitude of S wave is generally bigger than that of P wave for the natural earthquake, in the case of artificial earthquake, P wave is frequently larger than S wave, so that artificial earthquake can be distinguished using the ratio between P and S wave amplitudes. Moreover, infrasound waves can occur by artificial earthquake as it mainly occurs near the earth's surface, and they may be used for discriminating artificial earthquake by analyzing infrasound.



Automatic Analysis System for Artificial Earthquake Discrimination

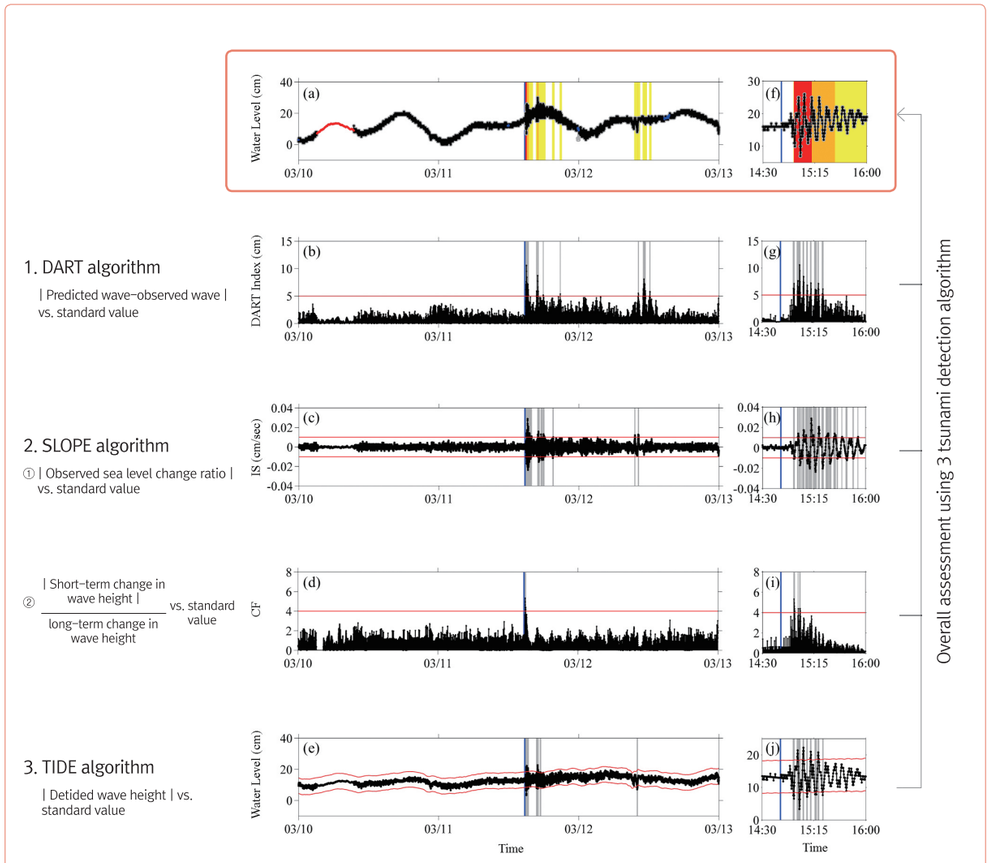


Infrasound Analysis

Tsunami

1. Tsunami Observation Method Development

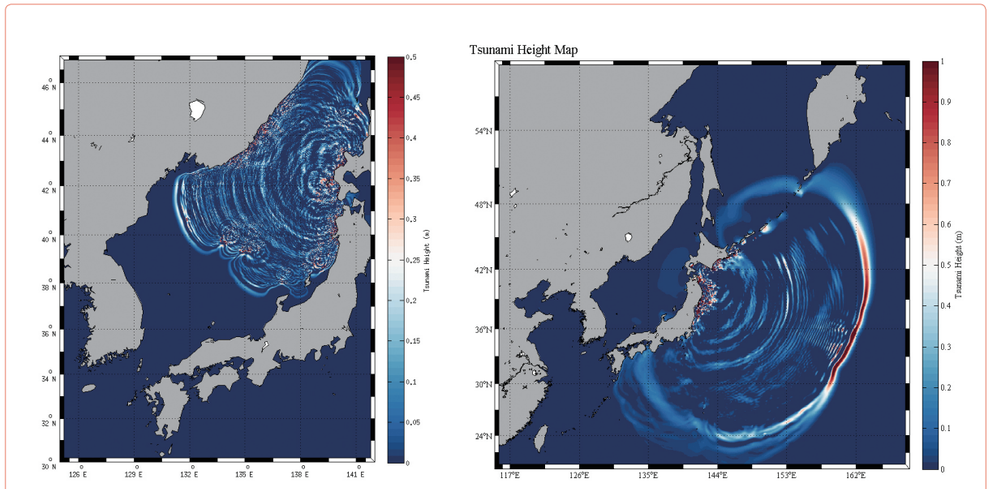
To observe tsunami, sea level data such as tsunami wave gauge and tide gauge are used. Sea level changes diversely by many factors other than tsunami such as tide and ocean waves. Therefore, tsunami detection methods using sea level data are being developed for the application to tsunami observation.



| Tsunami observation using tsunami detection algorithms |

2. Advanced Tsunami Prediction Technology

If tsunami occurs in the East Sea, since it reaches the Korean Peninsula in a short time, the KMA uses pre–constructed tsunami scenario DB for alert in order to provide tsunami information immediately so that one can prepare for tsunami beforehand. The tsunami scenario DB was constructed assuming fault geometry that can maximally influence the Korean Peninsula so that one can search for the tsunami information from the DB using only earthquake location and magnitude. The fault geometry assumed here may be different to that of actual earthquake. Thus the tsunami information on the scenario DB may be overestimated or underestimated compared to the actual tsunami. Therefore, information must be provided by predicting tsunami after applying the actual fault information when an earthquake occurs. Yet, since it takes considerable time for tsunami simulation, the development of techniques for tsunami simulation with sufficient accuracy and reasonable calculation time is required.

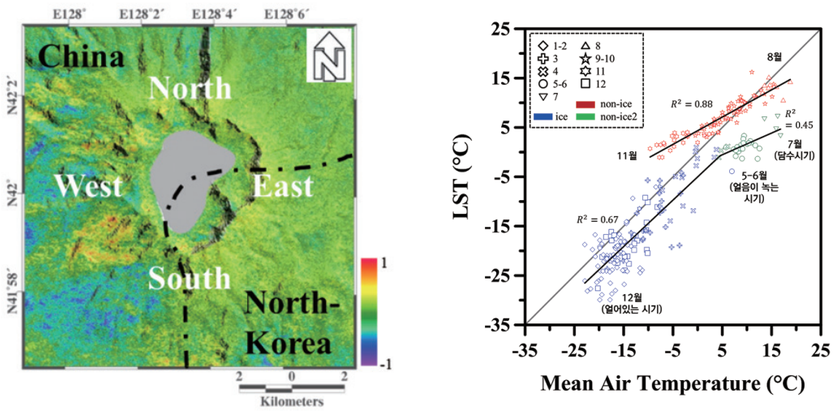


| Examples of Tsunami simulation |

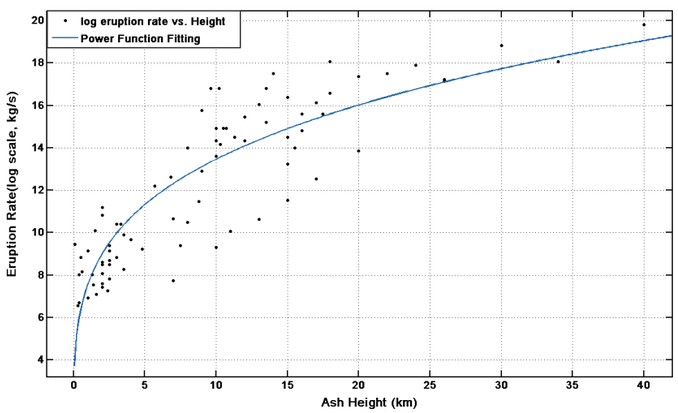
Volcano

1. Technology Development for Advanced Volcano Information

In order to monitor the volcanic activity of Baekdusan, which is one of the active volcanoes on the Korean Peninsula, surface displacement and surface temperature are being regularly analyzed using satellite data. Furthermore, volcanic ash diffusion model is being operated to analyze influence on Korean Peninsula due to volcanic ash diffusion when volcano erupts near the Korean Peninsula. Related research such as the relationship between ash plume height and eruption amount is being conducted to improve the accuracy of volcanic ash diffusion model.



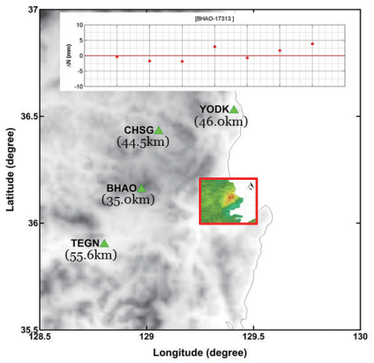
Surface displacement and temperature analysis on Baekdusan



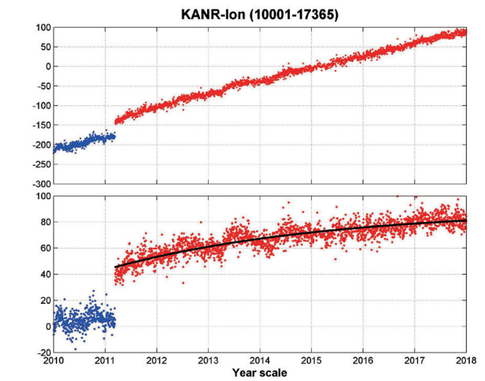
Relationship between ash plume and eruption amount of volcanic ash

2. Research on Influence of Earthquake and Volcano

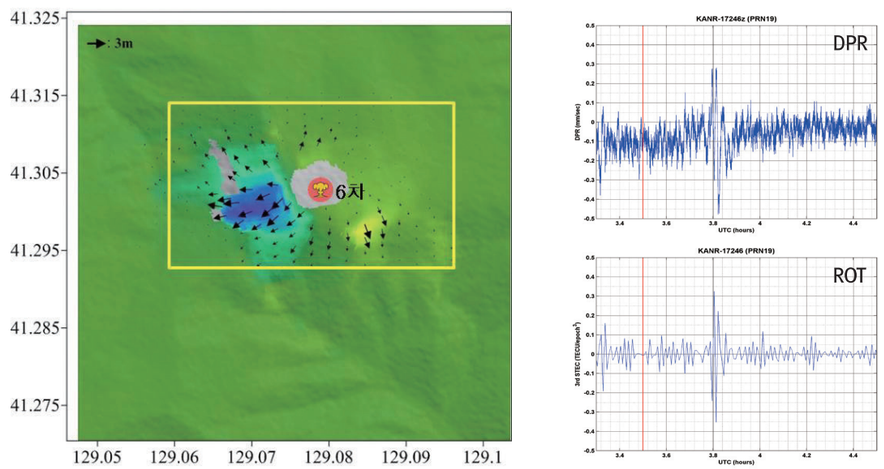
Earthquake and volcano can influence in various way, and the influence can be observed through diverse geophysical data. A research using GNSS (Global Navigation Satellite System), SAR (Synthetic Aperture Radar) satellite and geomagnetic data is being conducted to understand earthquake and volcano activity by observing the change before and after the events.



Surface deformation analysis due to 2017 Pohang Earthquake using SAR satellite and GNSS data



Crust movement analysis on the Korean Peninsula after 2011 Tohoku, Japan Earthquake



Surface deformation and ionospheric change analysis due to North Korea nuclear test

DOMESTIC AND INTERNATIONAL COOPERATION NETWORK

"Advancement in Observation·Anaysis·Information Service of the KMA through more information sharing and technology exchange"

The KMA is continuing cooperation to minimize damage to the people, property and infrastructure from disaster due to earthquake, tsunami and volcano.

Domestic Cooperation Network

By composing an observational institution council of 12 institutions that operate earthquake, tsunami and volcanic observatories, integrated observation network establishment and observation data sharing are being pursued. Furthermore, by strengthening cooperation with diverse related institutions such as the Ministry of the Interior and Safety, Ministry of Foreign Affairs, Ministry of Education, Ministry of Science and ICT, the national earthquake service is being further improved.

Observation Institution Council (Korea Hydrographic and Oceanographic Agency, National Geographic Information Institute, Korea Gas Corporation, Korea Rural Community Corporation, Korea Water Resources Corporation, Korea Institute of Nuclear Safety, Korea Electric Power Corporation, Korea Institute of Geoscience and Mineral Resources, Korea Institute of Ocean Science & Technology, Korea Hydro & Nuclear Power Corporation, Korea Radioactive Waste Agency)

International Cooperation Network

The KMA is hosting regular cooperation meetings with Japan Meteorological Agency (JMA) and China Earthquake Administration (CEA) and is conducting information sharing and technological exchange near the Korean Peninsula. In addition, it is sharing the information with many international institutions and organizations that operate observatories worldwide and maintaining a cooperative relationship.

* ICG/PTWS : The Intergovernmental Coordination Group for the Pacific Ocean Tsunami Warning and Mitigation System
* CTBTO : Comprehensive Nuclear-Test-Ban Treaty Organization
* IUGG : International Union of Geodesy and Geophysics
* IRIS : Incorporated Research Institutions for Seismology data management center
* GEO : Group on Earth Observation
* ISC : International Seismological Centre

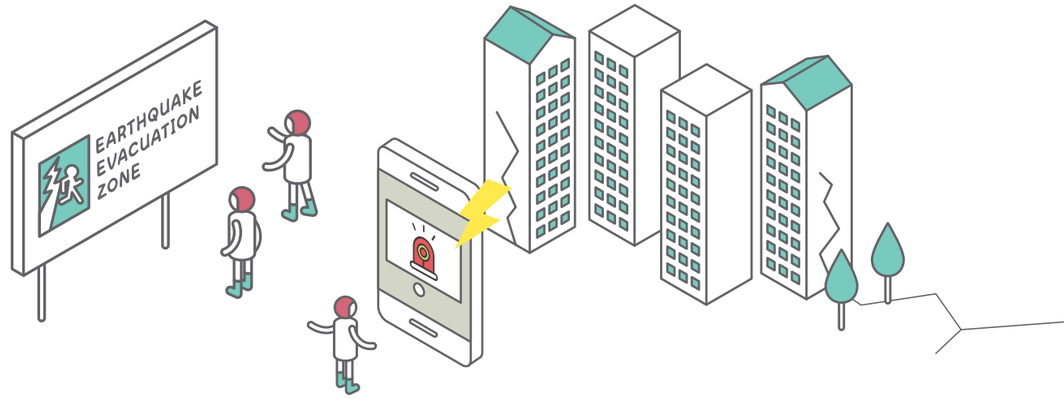
How to receive Earthquake Information

Public

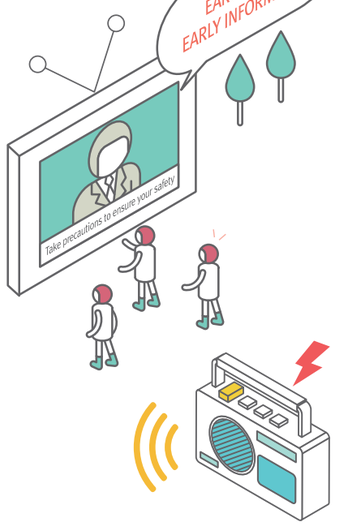
Earthquake Cell Broadcasting Service (CBS), TV subtitle, KMA Homepage, 131 ARS, mobile messenger (LINE), portal site, mobile safety application etc.

Disaster response related institutions and media agencies

Computer alert (PC client), FAX, SMS etc.



TV subtitle
Radio
131 ARS



Cell Broadcasting Service

KMA Homepage

www.weather.go.kr

Portal site

NAVER Daum

Mobile

Safety application

www.facebook.com/EarthTwist

@KMA_earthquake

Korea Meteorological Administration

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