Analysis of Site Effects at the Sagami Bay Strong Motion Stations for Real Time Application

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The large scale installation of cable linked network of ocean bottom seismographs (OBS) and pressure gauges (S-net) is undergoing in the Japan Trench area for more accurate and rapid early warning of earthquake and tsunami. It is expected that the data recordings will begin in this year. Previous studies of ground motions recorded at the OBS in the Nankai Trough area in Japan showed that the amplitudes of the ground motions at the OBS are significantly larger than those recorded at the land stations at equal distances. The studies elucidated that the main reason for the large amplitude motions at the OBS is the large amplification effects of low velocity layers beneath the stations. The studies have, therefore, recommended correction for the magnitude estimated by using the current procedures for OBS data. It is important to devise a methodology for accurate magnitude estimation applicable to the S-net seismic data as the S-net stations are expected to record the far offshore events first in the Japan Trench area. In this paper, we obtain site amplifications by spectral inversion method at the K-NET OBS in the Sagami Bay area. There are six such stations, namely KNG201 through KNG206, in the Sagami Bay area. In the inversion, we also included land stations in the Kanto area. Theoretical amplification factors based on PS-logging data at the KNGH21 KiK-net site are used as constraints to minimize the tradeoff between the various parameters. We used recordings from moderate events (Mw 4 ~ 6) and epicentral distances between 30 to 300 km. The PGAs are mostly < 100 gal for the recordings. The obtained results show that the sites at the Sagami Bay area experience amplifications by five to ten folds compared to the reference KiK-net site in wide frequency ranges. These results are similar to those reported for the Tonankai sea floor areas in Japan. Previous researches have shown that the amplifications of high frequency ground motions may differ substantially due to nonlinear site response during strong shaking. It is, therefore, important to consider the effects of nonlinear site amplification as well. This paper focusses mainly on the linear site amplification. We will examine the nonlinear site amplification effects on the OBS recordings in our future study. In this study, the estimated magnitudes based on the inverted source spectra agree well with the F-net Mw. We also found that the estimated Qs values are in the range of previous studies.

Keywords: Ocean bottom seismographs, S-net, Site effects, Spectral inversion, Sagami bay

Determination of the coefficients of M_{hdd} for regional data

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Hara (2007, EPS) developed a formula to calculate magnitudes using durations of high frequency energy radiation (HFER) and maximum displacement amplitudes using tele-seismic P waves. Hara (2013, SSJ) referred to a magnitude calculated by this formula as M_{hdd}. Hara (2014, JpGU) tried to revise the coefficients of the formula by a grid search to reduce the dependences of differences between M_{hdd} and M_w on epicentral distance and HFER duration. M_{hdd} calculated by the obtained coefficients were underestimates for larger earthquakes.
Hara (2015, SSJ) investigated the characteristics of M_{hdd} for tele-seismic data by another grid search, in which the dependence of M_{hdd} on M_w was taken into account in addition. He proposed a revised formula with small dependences of the differences between M_{hdd} and M_w on epicentral distance, HFER duration, and M_w allowing a slightly larger RMS of their differences.
In this study, we applied the procedure of Hara (2015) to regional data to determine the coefficients of M_{hdd} appropriate for regional distance range. We used broadband data recorded at FDSN stations in the epicentral distance range between 10 and 30 degrees for 60 events that occurred in between 1995 and May 2015. We retrieved data from the IRIS DMC. We conducted the grid search for the M_{hdd} coefficients following Hara (2015) and evaluated the dependences of the differences between M_{hdd} and M_w on epicentral distance, HFER duration, and M_w. As was observed for tele-seismic data, there is a significant M_w dependence for the set of the coefficients which provides the minimum RMS of the differences between M_{hdd} and M_w. As Hara (2015) showed for tele-seismic data, when we allow a slightly larger RMS of their differences, it is possible to find a set of the coefficients for regional data for which the dependences of their differences on epicentral distance, HFER duration, and M_w are small.

Keywords: Magnitude, High frequency energy radiation

Magnitude estimation for Earthquake Early Warning applicable for various seismic networks including OBS

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In JMA EEW system, since source parameters (hypocenter and magnitude) are determined quickly by using real-time data from several stations near the source region, stable observation record near the source area is important for EEW. In recent years, large-scale ocean bottom seismic networks, such as S-net (NIED), DONET1 and DONET2 (JAMSTEC) are currently under construction to make use for real-time monitoring, and it is expected that those OBS systems contribute to rapid EEW issuance. However, several problems were revealed for utilizing OBS data to EEW. One of these problems is acceleration offset caused by slight inclination change of OBS and/or hysteresis of sensors. From the analysis of Off-Kushiro OBS (JAMSTEC) data, it was found that the acceleration offset caused by OBS inclination increases with increasing input acceleration (PGA) when OBS exposed strong shaking (over 100cm/s^2) (Hayashimoto et al, 2015, JpGU). Acceleration offsets from inclination or hysteresis of OBS were also found at DONET1.
Magnitude of JMA EEW is mainly determined from the maximum amplitude of 3-component vector summation of displacement waveform. Here displacement waveforms are obtained from acceleration waveforms using the recursive filter by which waveforms are integrated twice and high-pass filtered at 6s. When acceleration offset appears within an acceleration waveform, EEW Magnitude might be overestimated because acceleration offsets lead to the displacement waveforms with large displacement offsets.
In this presentation, we focus on the characteristics of inclination change of OBS. It is found that the acceleration offsets are larger on the horizontal component (perpendicular to the cable line) than the vertical component and the other horizontal component (along the cable line). We proposed new magnitude estimation for EEW by using the maximum amplitude of vertical component displacement waveform. We found that overestimation of magnitude due to the inclination of OBS is able to reduce by using vertical component. Furthermore, it is found that variance of magnitude estimated at each stations becomes small by using vertical component. These improvements can be confirmed not only OBS network but also land stations. By using vertical displacement waveform, we would be able to reduce the effect of difference of site amplification factor and to estimate more stable magnitude.
Acknowledgement: The strong ground motion acceleration waveform data used in this study were obtained from the Japan Meteorological Agency (JMA) network, DONET and Off-Kushiro OBS of the Japan Agency Marine-Earth Science and Technology (JAMSTEC), K-NET and KiK-net of the National Research Institute for Earth Science and Disaster (NIED).

Keywords: Ocean Bottom Seismograph, Earthquake Early Warning, Magnitude estimation, Inclination, Site amplification

Development of the gathering and analyzing system for seismic response by use of the sensor cloud technology

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Strong motion seismometer network covering all over the country as typified by the K-NET, KiK-net, and the data center which accumulates seismic data recorded by these seismometers have been developed and maintained in Japan for approximately 20 years. Such valuable observation systems have been supported by a number of human resources and investments.
On the other hand, we have been developing the “Sensor Cloud” technology intended to be utilized for a rapidly damage detection of buildings or a real-time data transmission, taking an approach of sensing technology and IT technique such as the cloud computing.
Currently, we are mainly developing the “Sensor Cloud” system by utilizing MEMS (Micro Electro Mechanical Systems) acceleration meters inside mobile terminals. But, we intend to use other micro-sensors such as GPS, gyro, and video pictures. By utilizing these multi-sensors, we aim to capture the seismic response of the building in three dimensions, and then, archive the data on a cloud environment, finally, make benefits of seismic damage estimations.
Until now, we have been performed many monitoring experiments by utilizing plural sensors installed in different types of buildings. These records have been uploaded to the cloud server in a few minutes via internet. Then, we can easily download these data by clicking icons plotted on the map. Moreover, we can make easy analyses such as integral, FFT, orbit, or Seismic Intensity, only by the web browser.
By adding these new features, citizens who have no experiences of analyzing seismic data become available to install their own seismometers, and they can compare waves recorded by another areas from the standpoint of an amplitude or a predominant frequency.
However, these data are not always desirable for owners of each buildings. So, we have developed the hierarchic structure of an account and a limitation of access by the authentication.
As described above, we have produced the correcting and analyzing system working on the cloud recorded by MEMS acceleration sensors inside mobile terminals. In the future, we are going to develop archiving system recorded by multi-sensors, and also we are going to apply machine learning techniques to a large amount of these data.
Finally, it is important to regard not only with a view of the developer but also the user to develop these system as the social implementation. So, it is crucial to cooperate with experimental partners including governments, companies, and citizens.
Acknowledgement:
A series of this research partly owe to the discussion in the “Sensor Cloud study meeting”. So, we express our thanks to all members of the meeting and all cooperators of these experiments.

Keywords: Sensor, Cloud, Network

An approach for real time data acquisition from seismic intensity meter maintained by a local government -Case study on Tottori prefecture -

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An approach to use real time data from seismic intensity meter maintained by a local government is demonstrated in this presentation. Dense observation network is desirable for upgrading accuracy and quality of Earthquake Early Warning System. Seismic intensity meters installed all municipalities before recently conducted great synoecism are suitable equipment for the purpose. The seismic intensity meters in Tottori prefecture are improved to broadcast peak ground acceleration and seismic intensity every one second. A system that applies the packet data to estimate real time or prospective intensity distribution is prepared. In addition, observed data analyses and field surveys using microtremors are conducted to evaluate site response at the seismic intensity observation stations for more accurate seismic intensity estimations.

Keywords: Local Government, Seismic Intensity Meter, Real Time

Real-time Earthquake Information Display System

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My laboratory have developed method of prediction of wave field(Hoshiba et al. 2015) and I have developed real-time earthquake information display system.
The system consists of data receiving program rcvt, data format transformation program shmdump and wave server program.
rcvt and shmdump are part of WIN System.
wave server has wave buffer on memory and send JSON format seismic wave data, seismic intensity data and maximum acceleration data to client at request from web browser.
Web browser accesses to wave server per second and display received data using JavaScript program in HTML file.
Wave server needs to process observed data over several hundreds stations and must have high performance processing.
I tested the performance of parallel processing for high performance using GPU.
JMA seismic intensity needs Fourier transform and it is important to speed up Fourier transform.
First, I tested performance of Fourier transform using several libraries.
Test environment consists of OS Windows 8.1(64bit version), CPU Intel Core i7-4770K(3.5GHz, 4 cores), GPU NVIDIA GeForce GTX 760, C compiler gcc 4.9, FFT library FFTW 3.3, FFT library for GPU cuFFT of NVIDIA CUDA Toolkit 7.5.
Number of data is 2 to the 22nd power(4 million).
Performance of cuFFT using GPU is 10 times of its of FFTW.
Next, I tested performance of JMA seismic intensity and real-time seismic intensity.
I used seismic data with 100Hz sampling and 5 minutes data period(number of data is 30000).
Performance of JMA seismic intensity using FFTW is lower than real-time seismic intensity but performance using GPU is faster than real-time seismic intensity.
I plan to test application of GPU to multi station data using parallel processing.
References
1) Mitsuyuki Hoshiba and Shigeki Aoki, Numerical Shake Prediction for Earthquake Early Warning: Data Assimilation, Real-Time Shake Mapping, and Simulation of Wave Propagation,
Bulletin of the Seismological Society of America June 2015 vol. 105 no. 3 1324-1338
2) Japan Meteorological Agency(JMA) Report, 1996,
Note on the JMA Seismic Intensity, Gyosei (in Japanese), 1996, pp.238.
3) Kunugi, T., S. Aoi, N. Nakamura, W. Suzuki, N. Morikawa, and H. Fujiwara (2013): An Improved Approximating Filter for Real-Time Calculation of Seismic Intensity, Zisin (Journal of the Seismological Society of Japan),

Keywords: earthquake information, GPU, parallel processing

The removal of noise to detect volcanic earthquakes which occurred under Hakone volcano

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There are many kinds of volcanic earthquakes. However, the methods, criteria, and thresholds for their classification are not unified and strongly depend on a researcher and a volcano (Nishimura &Iguchi, 2006). Such dependence in the classification is confusing, and a unified classification framework is desired. Establishment of the framework should be based on enough examples of volcanic earthquakes extracted from continuously recorded seismic data. To that end, at first, to extract volcanic earthquakes from seismic records is required.

However, seismometers installed near a volcano frequently record human-driven noise as well as volcanic earthquakes. Therefore, we should discriminate volcanic earthquakes from other events. For the discrimination, we should investigate a continuous seismic record including signals of many volcanic events and human-driven noise simultaneously. In addition, we should also investigate an inactive term of the volcano because human-driven noise will dominate and be extracted easily from a record at that term; it allows us to understand the intensity and dominant frequencies of the human-driven noise. The understanding may contribute to extracting human-driven noise from seismic records obtained in an active term of the volcano.

From the point mentioned above, we investigate Hakone volcano, which was active from April to September in 2015. We used a continuous seismic record of the Ninotaira observation station published by Japan Meteorological Agency. The continuous record observed at the Ninotaira observation station has been repeatedly contaminated by characteristic waveforms due to every passage of trains near the observation station. Acausality between the waveforms and trains is obvious because the appearance of the waveforms and scheduled arrival and departure of trains described in a timetable of the train are simultaneous.

Using the record, we develop a method to detect noises due to the train passage regarding some of them as templates. First, we divide 20 waveforms of the train noise extracted between 5AM-9PM of March 29, 2015, the day when the volcano is not active, into 54 packets. We regard these 54 packets as templates after calculating their envelopes and smoothing them with a moving average. Next, we apply the aforementioned procedure to the whole part of the continuous record and calculated correlation function of the processed record and the templates.

After evaluation of a threshold to detect the train noises from the correlation function, we can detect 112 out of 116 train passages on March 29, 2015. On the other hand, extra 300 seconds within 24 hours are judged as train noises although no train passed in the terms. This noise detection method may enable us to detect volcanic events in an active term of the volcano. Actually, by applying the method to a record of June 29, 2015, the day of the eruption, some of the train noises dominated by significant seismic signals are not detected. Hence, our development succeeded in view of our purpose, detection of signals due to the volcanic event.

Acknowledgments: We use the data of the Japan Meteorological Agency volcano observation network.

Keywords: volcanic earthquake

The ambient noise analysis for the Tatun Volcano Group, Northern Taiwan

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The Tatun Volcano Group (TVG) locates in the north part of Taiwan, where is close to the metropolitan Taipei with distance less than 20 km. Thus, the monitoring for the potential activity is required for geohazard assessment. Near forty broadband seismic stations have been installed in the TVG area to monitor the volcanic activity up to recent time. The dense seismic network with long-term continuous seismic data would provide the information to study the temporal or spatial change of properties of the TVG. In the study, we use ambient noise between stations to determine the temporal variation related to the 2014 M_L 4.0 Shilin earthquake, which is one of the largest event occurred in the TVG area. The daily empirical Green's functions are derived from cross-correlation of continuous vertical-component data during the time period one year before and after the earthquake occurrence. The time shift between specified and reference empirical Green's function is then estimated to detect the small seismic velocity change of the medium associated to the Shilin earthquake. Besides, the auto-correlation of individual stations nearby the main shock epicenter is also applied to improve the ability of detection.

Keywords: seismic ambient noise, cross-correlation

W-phase analysis and fault parameter estimation by using high-sampling-rate(1Hz) GNSS data (for the case of the 2003 Tokachi-Oki earthquake)

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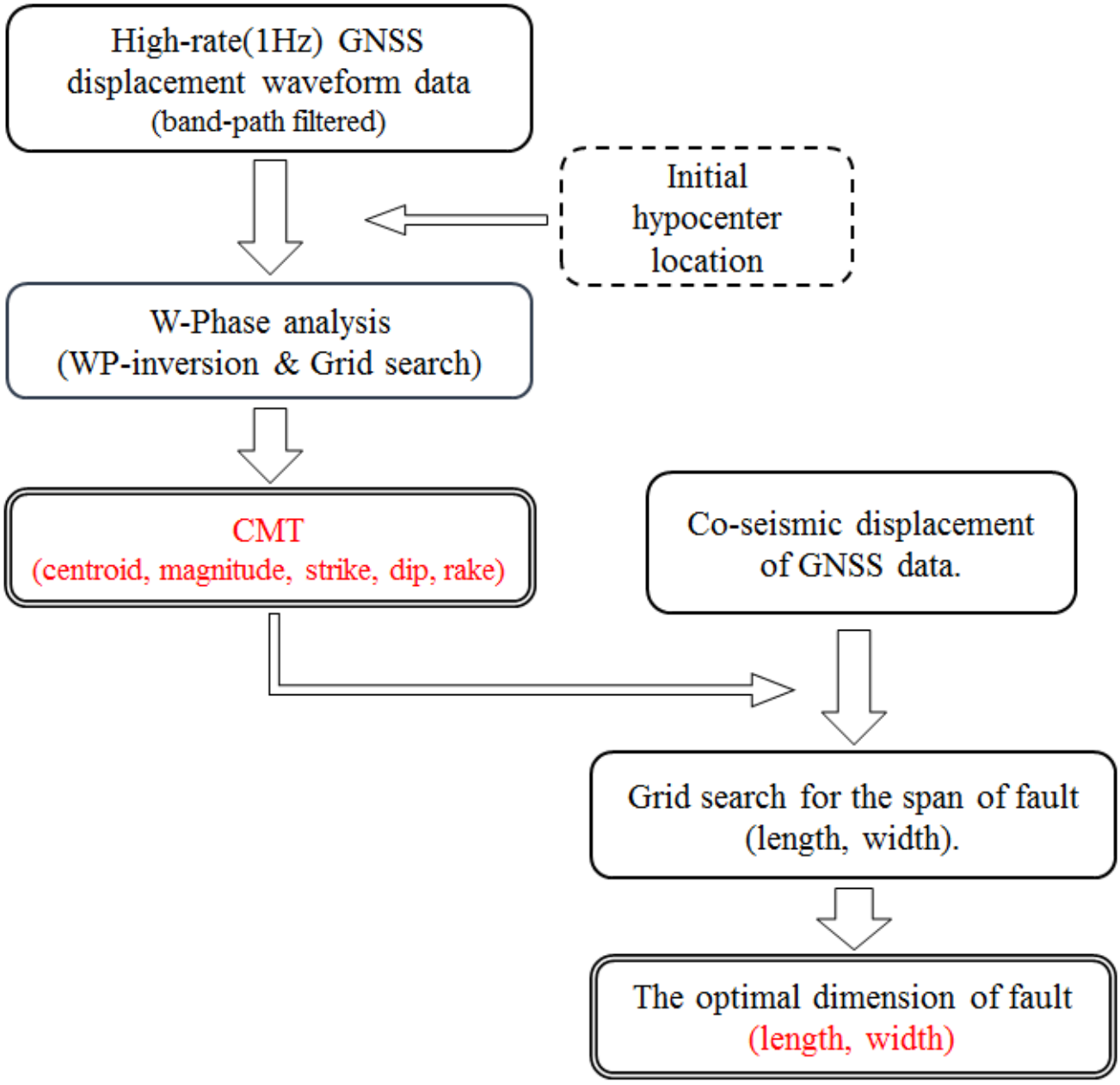
JMA has been issuing tsunami warning immediately, in about three minutes, when a large earthquake occurs in coastal regions of Japan. This initial warning is based on only the information of the hypocenter and the magnitude. Therefore, detailed analysis, such as a centroid moment tensor solution, are needed to update the warning.
Ueno et al. (2014) tried w-phase analysis for the 2011 Tohoku-Oki earthquakes (the main shock and the largest aftershock) using high-sampling-rate (1Hz) GNSS data. Furthermore, Miyaoka et al. (2014) tried to estimate length and width of the fault using the coseismic crustal deformation data observed at each GNSS sites based on the result of the w-phase analysis described above.
These study showed a possibility to obtain the CMT solution and the fault size in six or seven minutes after the event occurrence and pointed out the necessity to analyse other cases.
In this study, we applied these analyses to a case of the 2003 Tokachi-Oki earthquake. We would like to show the result of the analysis.

Keywords: W-phase, GNSS 1Hz data, 2011 Tohoku-Oki earthquake, 2003 Tokachi-Oki eqrthquake



Study on matching method of the ocean bottom pressure waveforms toward real-time tsunami forecast

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We are developing a real-time forecast system of the tsunami inundation as well as the coastal tsunami heights for the Pacific coast of Chiba prefecture (Kujukuri and Sotobo regions), using the real-time ocean bottom pressure data (Aoi et al., 2015) observed by the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net; Kanazawa et al., 2012; Uehira et al., 2015). We employ the database-driven method to forecast the inundation, which is a nonlinear phenomenon, for relatively broad region. We use the densely observed data set probably including the data obtained in or close to the tsunami source area to perform the rapid and accurate tsunami forecast. The database is called as “Tsunami Scenario Bank” and includes “Tsunami Scenario” composed of the possible tsunami source model, and the simulation results of the ocean bottom pressure data at S-net observation stations, coastal tsunami heights, inundation areas and flow depth, for each source model (Suzuki et al., 2015). The system starts to search scenarios whose ocean bottom pressure data match the observed data reasonably well. Selected scenarios from this matching then provide the information of forecasted tsunami heights, inundation areas and flow depth, adequately considering the uncertainties of the forecast. Now, the matching algorithm implemented for the forecast system compares the spatial distributions of ocean bottom pressure changes using the correlation coefficient and two kinds of variance reductions (Yamamoto et al., 2016). To advance the robustness of forecast and warning, it is better to implement several different approach for real-time tsunami detection and forecast. In this study, therefore, we examine the matching for the time series of the ocean bottom pressure change at each station for selecting the tsunami scenarios that explain the observation well.
To evaluate the fitness between the observed and scenario pressure data, we examine the L1 norm---the absolute values of differences---and L2 norm, which corresponds to the least square evaluation. We applied the two norms to the synthetic ocean bottom pressure data at 150 S-net stations calculated from the tsunami source model of the 2011 Tohoku-oki earthquake. For scenario bank, the results calculated from the non-linear tsunami simulation based on approximately 1,800 tsunami source models that would affect the Pacific coast of East Japan (Hirata et al, 2014). Matching using both L1 and L2 norms resulted in slightly underprediction for the amplitude of coastal tsunami height as well as the amplitude of the ocean bottom pressure data. In addition, we found that matching with the L1 norm tends to underestimate the tsunami scale more in the early stage of the tsunami propagation. We will, then, comprehensively capture the characteristics of the evaluation using the L1 and L2 norms from the examination of the other synthetic tsunami data and develop the appropriate method to match the observed and scenario ocean bottom pressure data.
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Keywords: Real-time tsunami forecast, Tsunami inundation, Scenario bank, S-net

