Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

HDS26-01 Room:102B Time:May 21 09:00-09:15

JMA's Tsunami Warning Improvement Plan

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After the devastating damage caused by the 2011 off the Pacific coast of Tohoku Earthquake, the Japan Meteorological Agency (JMA) established the Advisory Meeting for Tsunami Warning Improvement (June-September 2011) to consider the strategic plan on JMA's tsunami warning improvement, inviting tsunami experts and relevant disaster management organs. Based on the Advisory Meeting's discussion, JMA crafted the Tsunami Warning Improvement Plan in September 2011. To tailor the expression of tsunami warning messages along the context of the plan, JMA held another advisory meeting, i.e., the Advisory Meeting on Tsunami Warning Criteria and Bulletin (September 2011 to January 2012), focusing on. The Advisory Meeting summarized the recommendation on tsunami warning criteria and expression of warning messages in February 2012. In this paper, the measures to improve JMA's tsunami warning in line with the above mentioned improvement plan and recommendation are outlined.

The major issue of JMA's tsunami warning for the 3.11 event was that the 1st bulletin of tsunami warning issued three minutes after the quake was based on underestimated Mjma7.9, and thus underestimated tsunami height of 3m or 6m might have resulted in the delay of evacuation. Mjma, equivalent to surface wave magnitude (Ms) for shallow events, has an advantage of fast availability, but inherently saturates at around 8. To deal with this problem, JMA will introduce tools with which validity of Mjma estimation can be evaluated before the 1st tsunami warning issuance. If the possibility of much larger magnitude than Mjma estimation is detected by the tools, JMA will issue tsunami warning by replacing the magnitude by the maximum credible magnitude around the region close to the epicenter. In this case, as there is large uncertainty of tsunami height estimation, JMA will not issue tsunami height estimation numerically but qualitatively aiming at conveying emergency situation to the people.

For the 3.11 event, JMA could not calculate Mw within 15 minutes as with JMA's normal operation, because very large seismic waves went off the scale of most of JMA's broadband seismographs. And offshore tsunami observation data of cabled ocean-bottom pressure gauges deployed around Japan could not be applied for tsunami warning update. These issues led to the delay of tsunami warning upgrade for the 3.11 event. In order to deal with these matters, JMA is planning to deploy 80 new broad-band seismographs with larger measuring range to calculate Mw within 15 minutes in case of such a huge earthquake as the 3.11 event, and promote the utilization of ocean-bottom pressure gauges. In the updated tsunami warning bulletin based on Mw, tsunami height estimation is expressed numerically, because the uncertainty is diminished enough at this stage.

Tsunami height categorization will be decreased from eight (0.5m, 1m, 2m, 3m, 4m, 6m, 8m, >=10m) to five (1m, 3m, 5m, 10m, >10m), taking into account the realistic variation of countermeasures in time of emergency and forecast error range. Estimated tsunami height shown in the bulletin is the maximum value in the margin of error.

The above described tsunami warning improvement measures will be put into operation by the end of 2012, subject to the schedule for system modification of not only JMA but also the organs responsible for transmitting and using tsunami warning bulletin.

Keywords: Tsunami warning, Improvement plan

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Table 1: Category and criteria of tsunami warning and tsunami height estimation

<table>
<tr><th colspan="2" rowspan="3">Category</th><th>Present</th><th colspan="3">Improvement Plan</th></tr>
<tr><th rowspan="2">Expression of tsunami height</th><th colspan="2">Expression of tsunami height</th><th rowspan="2">Estimated height</th></tr>
<tr><th>Numerical</th><th>Qualitative</th></tr>
<tr><td rowspan="4">Tsunami Warning</td><td rowspan="3">Major Tsunami</td><td rowspan="3">10 m or more, 8m, 6m, 4m, 3m</td><td>Over 10m</td><td rowspan="3">Gigantic *)</td><td>10m -</td></tr>
<tr><td>10m</td><td>5m – 10m</td></tr>
<tr><td>5m</td><td>3m – 5m</td></tr>
<tr><td>Tsunami</td><td>2m, 1m</td><td>3m</td><td>High *)</td><td>1m – 3m</td></tr>
<tr><td colspan="2">Tsunami Advisory</td><td>0.5m</td><td>1m</td><td>(Blank)</td><td>0.2m – 1m</td></tr>
</table>

*) Expression in English is under consideration.

Japan Geoscience Union Meeting 2012
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HDS26-02 Room:102B Time:May 21 09:15-09:30

Research for Improvement of the JMA Tsunami Warning System

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1. Introduction

The 2011 off the Pacific coast of Tohoku Earthquake that is the largest earthquake of Mw=9.0 ever recorded in Japan has caused devastating damages especially by a gigantic tsunami. So many lives were lost by the tsunami, even though Japan Meteorological Agency (JMA) had issued a tsunami warning 3 minutes after the occurrence of the earthquake. So, JMA set up a committee consisting of academic and administrative experts to investigate the problems that should be solved for a better tsunami warning system. This presentation will introduce an overview of our project that aims to develop new techniques to solve the problems pointed out by the committee.

2. Problems for the Current Tsunami Warning System

The committee report says there are two major technical problems to be improved.

1) The first tsunami warning issued 3 minutes after the earthquake underestimated the tsunami heights because the magnitude was underestimated as M=7.9 at that time, and JMA could not recognize the fact of underestimation. It is crucial to develop a technique to estimate magnitude correctly for great earthquakes such as over M8.0 in a short enough time to issue the first warning.

2) The moment magnitude, which should have been calculated within 15 minutes after the earthquake, could not be calculated because of the scale out of the broad-band seismometer. Besides, the information of tsunami arrival at offshore area that was observed by ocean bottom pressure gauges (OBPGs) was not well utilized to update the tsunami warning, because the technique to utilize that information had not well been established. These prevented a prompt renewal of tsunami warning.

3. Improvement of the Tsunami Warning System

To overcome the above mentioned problems we are conducting the following researches.

1) We are developing methods to estimate the magnitude correctly for great earthquakes in a short time, or at least to judge if the magnitude becomes larger than 8.0. Four methods are proposed to estimate the magnitude and listed below.

- Method using the distribution of strong ground motion area
- Method to estimate Mwp using P arrival wave forms
- Method using duration times of strong ground motions
- Method comparing wave forms filtered with various frequency bands

2) In order to utilize the information of offshore arrival of tsunami waves, we are developing a new technique. The method consists of two steps. First, we estimate the initial variation of sea surface caused by an earthquake by applying the inversion method to the observed offshore tsunami waveform data. Then we forwardly calculate the tsunami waveforms along coasts using the estimated initial distribution of sea surface elevation. This method is applicable to forecasting tsunamis caused not only by earthquakes but also by marine landslides. As for enhancement of the offshore observation network, JMA is planning to deploy three buoy-type OBPGs late in 2012.

3) In the tsunami forecast using offshore data, the accuracy of observed tsunami plays an important role. But, there are two difficulties in getting precise tsunami waveforms when we use OBPG data observed near the seismic source region. The first is a problem concerning the thermal response of the pressure gauge to sudden temperature change on deep ocean floor. The second is to resolve the tsunami signals from contaminated high frequency pressure fluctuation that is caused by a nearby earthquake. To overcome the difficulties, we are estimating the characteristics of OBPG data and planning to develop a new type of OBPG.

4) JMA is planning to deploy the broad-band strong motion seismometers at 80 stations over Japan that do not scale out against strong ground motion, which will enable us to calculate Mw within 15 minutes after a great earthquake.

Keywords: Tsunami Warning, JMA, Prompt Magnitude Estimation, Offshore Tsunami Gauge, Waveform Forecast

HDS26-03 Room:102B Time:May 21 09:30-09:45

Rapid coseismic displacement detection/estimation algorithm and its application to the 2011 Tohoku-Oki earthquake

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Real-time crustal deformation monitoring is extremely important for achieving rapid understanding of actual earthquake scales, because the measured permanent displacement directly gives us the true earthquake size (seismic moment, Mw) information. We have developed an algorithm to detect/estimate static ground displacements due to earthquake faulting from real-time kinematic GPS time series. Our algorithm identifies permanent displacements by monitoring the difference of a short-term average to a long-term average of the GPS time series [1]. We applied the algorithm to data obtained in the 2011 off the Pacific coast of Tohoku earthquake (Mw 9.0) to test the possibility of coseismic displacement detections, and further, we inverted the obtained displacement fields for a fault model. Estimated a fault model with Mw 8.7, which is close to the actual Mw of 9.0. We also applied the algorithm to data of aftershocks of the 2011 M9 earthquake. We succeed in detecting the coseismic step caused by Iwate-oki earthquake (March 11, 15:08 (JST), Mw 7.4) and Ibaraki-oki earthquake (March 11, 15:15 (JST), Mw 7.7). For the Ibaraki-oki earthquake, we evaluated the coseismic fault model estimation. The inversion estimated a fault model with Mw 7.7, which is same with the actual one determined by the seismic data [e.g. 2].

The false detection of the permanent displacement should avoid for reliable warning system. Based on the long-term varied baselines and different reference sites posterior processing, we estimated the false detection rate reached ˜0.25% with 4-sigma confidential limit in single baseline. This false detection rate is inadequate to work for practical use in dense GPS network (many baselines) such as GEONET. We improved permanent displacement detection algorithm for reduction of the false detection rate. In the improved algorithm, the earthquake occurrence is defined as all neighboring GPS sites must be detected the displacement including oneself. We applied the improved algorithm to actual data set. The false detection rate clearly decreases with our improved algorithm, which is little more than zero. When we can use the several reference sites for the RTK-GPS data processing and compared with each reference site result, the false detection rate will become almost zero. The improved algorithm is also useful for small displacement detection because the threshold value is possible to cut down to 2 or 3-sigma confidential limit.

[1] Ohta et al., JGR, 2012 [2] Hirose et al., EPS, 2011

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HDS26-04 Room:102B Time:May 21 09:45-10:00

Global tsunami simulations from seismic CMT solutions: Developing a real time tsunami simulator

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Because the earthquake does not always occur with the anticipated magnitude, it is important to quantitatively predict tsunami height and its arrival time based on a real-time simulation with the seismic magnitude and the mechanism correctly estimated from the observed seismograms. This study develops a tsunami simulator that calculates the tsunami propagation from the seismic CMT solution estimated by the real-time seismogram analyses. The simulation is conduced with the whole earth model in order to calculate the tsunami from the earthquakes occurred in any oceans and include all the waves scattered from all the coasts and sea-bottom topography. Focusing on the tsunami in offshore regions, which does not show strong nonlinear behavior, we can rapidly synthesize the tsunami waveforms from arbitrary initial tsunami-height distributions by superposing the Green's functions loaded from the database constructed in advance.

In order to examine the validity of this simulator, we conducted a tsunami simulation for the 2011 Tohoku-oki earthquake. The moment magnitude of the CMT solution was estimated as MW 8.8 from the seismograms recorded by the velocity-type strong motion seismographs in Japan. Employing a scaling relation between the moment magnitude and the earthquake fault size, we obtained a uniform slip of 15 m on the fault of 300 km in length and 150 km in width. We calculated the initial tsunami height distribution from the fault model and simulated the tsunami propagation from the tsunami source. The simulation can successfully reproduce the tsunami height more than 4 m off the coast of Miyagi (observed height is ~5.8 m, and calculated is ~4.8 m). However, it was difficult to reproduce the detail of the waveforms because we employed a simple fault model in the simulation.

For the 2006 Kuril earthquake, tsunami warning/advisory was issued at the Japanese coast of the Pacific Ocean and canceled the warning/advisory 5 hours after the earthquake occurrence. But, the maximum tsunami height arrived at some parts in northeastern Honshu, Japan after the cancelation. The tsunami scattered from the Emperor seamounts constitutes the maximum tsunami height [e.g. Koshimura et al. 2008 GRL]. The ocean-bottom pressure gauges located at Sagami bay recorded the leading tsunami and the maximum-height tsunami at 2 hours and 8 hours after the earthquake occurrence, respectively. Our tsunami simulator can successfully simulate the arrival times of both the leading wave and the maximum wave, whereas it was impossible to simulate the maximum tsunami arrival if we limit the simulation area to around Japan.

Keywords: tsunami, simulation, CMT solution

HDS26-05 Room:102B Time:May 21 10:00-10:15

Tsunami simulation using submarine displacement calculated from simulation of ground motion due to seismic source model

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Since fault fracturing due to an earthquake can simultaneously cause ground motion and tsunami, it is appropriate to evaluate the ground motion and the tsunami by single fault model. However, several source models are actually used independently according to whether the ground motion is evaluated or the tsunami, because of difficulty in evaluating both phenomenons simultaneously.

Many source models for the 2011 off the Pacific coast of Tohoku Earthquake are proposed from the inversion analyses of seismic observations or from those of tsunami observations. Most of these models show the similar features, which large amount of slip is located at the shallower part of fault area near the Japan Trench. That indicates that the ground motion and the tsunami can be evaluated by the single source model.

In this study, we try to carry out the tsunami simulation using the displacement field of oceanic crustal movements, which is calculated from the ground motion simulation of the 2011 off the Pacific coast of Tohoku Earthquake. First, the large-scale ground motion simulation based on the voxel type finite element method is performed for the whole eastern Japan. The fault model based on the teleseismic body wave, which is constructed by the Japan Meteorological Agency, is assigned to the source region. The synthetic waveforms by the simulation are generally consistent with the observation records of K-NET and KiK-net. Next, the tsunami simulation is performed by the finite difference calculation based on the shallow water theory. The initial wave height for tsunami generation is estimated from the vertical displacement of ocean bottom due to the crustal movements, which is obtained from the ground motion simulation mentioned above. Although the results of tsunami simulation show that synthetic waveforms are fairly consistent with the observations of the GPS wave gauges, the comparisons of synthetics and observation show that the tsunami simulation in this study underestimates the maximum wave height in most observing stations.

Although the results of these simulations generally indicate the possibility that a phenomenon of tsunami can be evaluated using the source model from seismic analysis, there remain difficulties in evaluation of the tsunami maximum wave height, which is one of the most important issues in disaster prevention.

Keywords: the 2011 off the Pacific coast of Tohoku Earthquake, tsunami, ground motion, source model, simulation

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HDS26-06 Room:102B Time:May 21 10:45-11:00

Ocean bottom seismic and tsunami network along the Japan Trench

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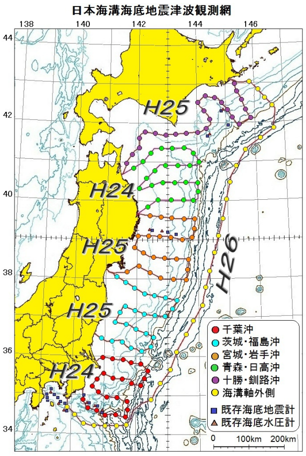
Huge tsunami, which was generated by the 2011 off the Pacific Coast of Tohoku Earthquake of M9 subduction zone earthquake, attacked the coastal areas in the north-eastern Japan and gave severe causalities and property damages in the areas. The present tsunami warning system, based on land seismic observation data, did not work effectively in the case of the M9 earthquake. It is strongly acknowledged that marine observation data is necessary to make tsunami height estimation more accurately. Therefore, new ocean bottom observation project has started in 2011 that advances the countermeasures against earthquake and tsunami disaster related to subduction zone earthquake and outer rise earthquake around Japan Trench and Chishima Trench. A large scale ocean bottom cabled observation network is scheduled to be deployed around Japan Trench and Chishima Trench by 2015. The network is consisted of 154 ocean bottom observation stations. Ocean bottom fiber optic cables, about 5100 km in total length, connect the stations to land. Observation stations with tsunami meters and seismometers will be placed on the seafloor off Hokkaido, off Tohoku and off Kanto, in a spacing of about 30 km almost in the direction of East-West (perpendicular to the trench axis) and in a spacing of about 50 - 60 km almost in the direction of North-South (parallel to the trench axis).

Keywords: Ocean bottom cable, Realtime observation, the Japan Trench, Tsunami monitoring, Ocean bottom seismic observation, Warnimg



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HDS26-07 Room:102B Time:May 21 11:00-11:15

An Offshore Experiment of Tsunami Monitoring System using GPS Buoy

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In the process of development of a GPS tsunami meter, the basic experiment in the Sagami bay, the utilization experiment off Ofunato, and the actual proof experiment off Muroto have been conducted. Five tsunamis were observed by a series of experiments. These observation results proved that the measurement accuracy of tsunami height was an order of cm. The Ministry of Land, Infrastructure, Transport and Tourism utilized the development result of the GPS tsunami meter, and started national deployment of the GPS buoy. The system has been adopted as a part of the nationwide ocean wave information system for port and harbors (NOWPHAS). The real-time tsunami records of 11th March 2011 Tohoku-Oki earthquake tsunami observed by GPS buoy of NOWPHS. Over 6m tsunami height is observed at the Off South Iwate (Kamaishi). The Japan Meteorological Agency which observed this data updated the level of the tsunami warning to the greatest value.

Currently, the GPS buoy system uses a RTK-GPS which requires a land base for precise positioning of the buoy. This limits the distance of the buoy from the coast to, at most, 20km. In order to overcome this problem, introducing a new algorithm of precise point positioning with ambiguity resolution (PPP-AR) method and point precise variance detection (PVD) method are planned for 100km offshore observation. Also, an open source program package (RTKLIB) for super-long baseline is applicable for this purpose. So, the new experiment at off Muroto is started just now using these GPS positioning methods. The positioning results will be exhibited in real time on the internet (http://www.tsunamigps.com/) after tuning the system. In this experiment, the fish float buoy named Kuroshiobokujou borrows for the GPS buoy under the cooperation of Kochi Prefecture.

Keywords: GPS, Tsunami-meter, PVD, PPP-AR

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HDS26-08 Room:102B Time:May 21 11:15-11:30

Sea-level observation with ultra-low power radio telemetry for the last minutes tsunami warning

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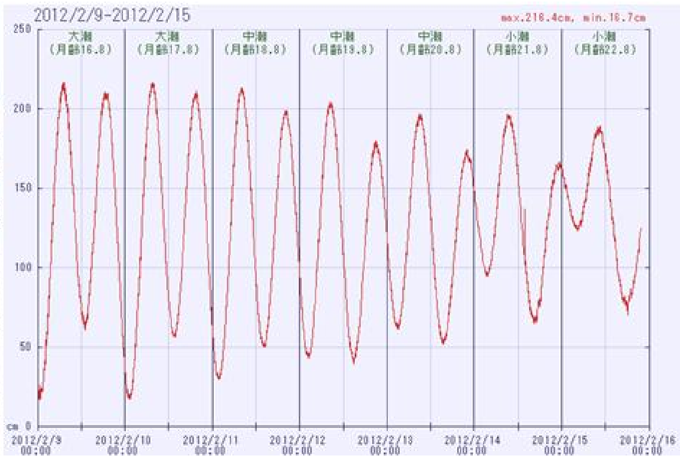
One of the reasons why many people have lost their lives by the Great East Japan Earthquake of March 11, 2011 is that the people could not realize the approaching massive tsunami due to various problems. If accurate information of tsunami, even only several minutes before arrival, was provided to the people, number of casualties would have been smaller. A network of ocean bottom cables and buoys to directly measure the sea level will be deployed along the Japanese coast to improve the early warning system. If tsunami approaching the cost, propagating in bays is monitored in the last some tens of minutes until it hits cities, people would be able to take more appropriate action of evacuation.

For such purpose we have to install tide gauges on near-shore islands, tip of a cape, and along the coast line of a bay. We develop a system which enables such installation using MAD-SS, a very slow but ultra-low power spread spectrum radio developed by Mathematical Assist Design Laboratory. It transmits only 1 byte per second, over the distance of 100km line of sight with only 10mW VHF radio. It can be operated more than several months by a pack of dry-cell batteries or a small solar panel. Unlike using cell-phone system, the radio telemetry is reliable even during a crisis and free of charge. The system consists of a water pressure sensor, a digitizer, and a radio transmitter built in a pipe, and easy to install.

We installed a system for testing at a breakwater on Kamishima Island located at the mouth of Ise-bay to transmit the data to Mie University campus in Tsu city 45 km away. Another system was tested at Hasaki Oceanographic Research Station of PARI, in Ibaraki Prefecture, for the purpose of developing installation method at sand beach, which gives more freedom to the location of installation. Deployment of the systems to Albay Gulf and Manila Bay of the Philippines, and Pandang Island off Padang, West Sumatra Indonesia are planned. Installing the system to Pacific Island Countries will contribute to enhance monitoring capabilities of distant tsunamis for the whole Pacific.

(We are grateful to Prof. Hanazato of Mie University and Dr.Nakamura and Mr. Yanagishima of Port and Airport Research Institute for proving their facilities for the observation.)



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Tsunami induced ionospheric disturbances detected by GPS-TEC observation after the 2011 Tohoku earthquake

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All the details of the commencement and evolution of ionospheric disturbances after the 2011 off the Pacific coast of Tohoku Earthquake were revealed by the high-resolution GPS total electron content observation in Japan. The initial ionospheric disturbance appeared as sudden depletions by about 6 TEC unit (20%) following small impulsive TEC enhancements around 05:54UT, about seven minutes after the earthquake onset, near the epicenter. At 06:00UT, zonally extended enhancements of TEC appeared in the west of Japan, and traveled to the southwest direction. From 06:00UT to 06:15UT, large-scale circular waves
with two peaks propagated in the radial direction in the propagation velocity of 3,457 m/s and 783 m/s for the first and second peak, respectively. Following the large-scale waves, medium-scale concentric waves appeared to propagate at the velocity of 138-423 m/s after 06:15 UT. In the vicinity of the epicenter, shortperiod oscillations with period of about 4 minutes were observed after 06:00 UT for 3 hours or more. We focus on the the circular and concentric waves in this paper. The circular or concentric structures of the large- and medium-scale waves indicate that these ionospheric disturbances had a point source. The center of these structures was located around 37.5 deg N of latitude and 144.0 deg E of longitude, 170 km far from
the epicenter to the southeast direction. We termed this center of the coseismic ionospheric variations as "ionospheric epicenter". According to the propagation velocities, the large-scale waves would be caused by the acoustic waves generated from the propagating Rayleigh wave for the first peak and from the sea surface near the epicenter for the second peak. The wavelength and the propagation velocity of the medium-scale concentric waves tended to decrease with time. This characteristic is consistent with the result of a numerical model of the coseismic atmospheric wave, indicating that these medium-scale waves were caused by the atmospheric gravity waves. The amplitude of the large- and medium-scale circular waves were not uniform depending on azimuth of their propagation direction, much larger in the north and west directions than other directions. This directivity could not be explained by the previously proposed theory.

Keywords: ionosphere, earthquake, tsunami, acoustic wave, atmospheric gravity wave, concentric wave

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HDS26-10 Room:102B Time:May 21 11:45-12:00

Generation and propagation of the 2011 Tohoku earthquake tsunami inferred from the OBEM array in the North-West Pacific

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The 2011 Tohoku earthquake tsunami caused a destructive damage along the shoreline from the Tohoku to Kanto districts. Because many of the tide gauge stations along the Tohoku coast were damaged by the tsunami, source process of the tsunami has not been well determined yet. After the Tohoku earthquake, several cruises of JAMSTEC research vessels recovered Ocean Bottom ElectroMagnetometers (OBEMs) from the seafloor sites in the North-West Pacific area, where the OBEMs had been installed before the earthquake. These sites are BM14 (39.058N, 144.808E, 5830m; recovered by NT11-08), NWP (41.103N, 159.952E, 5816m; recovered by KR11-07), and NM04 (38.211N, 154.190E, 5940m; recovered by KR11-10). OBEMs from these sites clearly recorded the ElectroMagnetic(EM) tsunami signals.

Seafloor measurement of the EM signals due to tsunamis had not been attained until very recently (Toh et al., 2011) because of their low signal levels. However, recent advances in technology enabled the seafloor measurements of the tsunami EM signals by using OBEMs. First simultaneous measurements of EM signals and bottom pressure during the passage of 2010 Chile earthquake tsunami in the French-Polynesia region (Hamano et al.,2011), proved that seafloor observation of EM signals is powerful tool to investigate the generation and propagation of tsunamis in the open sea, in which temporal variations of the vertical magnetic field, Bz, reproduce the variations of the sea level change due to the passage of tsunami wave, and two horizontal magnetic fields, Bx and By, indicate the propagation direction of tsunamis. As for the Tohoku earthquake, combination of the three OBEM stations with the tsunami monitoring stations ST2418 (38.718N, 148.698E, 5500m), ST21413 (30.528N, 152.123E, 5874m), and ST21419 (44.455N, 155.735E, 5285m) operated by NOAA, comprises an observational network for the tsunami located in the east of the fault plane of the Tohoku earthquake, which provides valuable information on the generation and propagation of the 2011 Tohoku earthquake tsunami. Among the network stations, the OBEM at site BM14 recorded the tsunami arrival after 4 minutes of the origin time of the Tohoku earthquake. This early observation at the closest place to the tsunami source enable reliable estimate of the source process of the tsunami (Ichihara et al., 2011). Here, we report the propagation process of the tsunami inferred from this tsunami observational network. By taking cross-spectra of the 24 hours signals of sea level change from each station correspond to the signals from BM14 (closest site to the tsunami source) , dispersion relations of the tsunami wave across the network were calculated. The result indicates that the tsunami generated just west to site BM14 propagates across the line from BM14 through ST21418 to NM14. This west to east propagated tsunami wave shows a dispersion relation consistent with the theoretical estimate of gravity waves corresponding to the water depth of 5500 m. The dispersion shows that the decrease of phase velocity by about 15 % from the period of 20 minutes to 3 minutes. Cross-spectra of the records from ST21413 and ST21418 to that from BM14 indicate that the tsunami arrived at these sites propagate along west-east direction, suggesting the sources for the tsunami passing through these two stations are different from the source responsible for the tsunami propagated along the BM14-ST21418-NM14 line.

Keywords: tsunami, electromagnetic observation, sea floor observation, ocean dynamo effect, 2011 Tohoku earthquake

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Magnitudes of the Aleutian Tsunamis in Nov. 2003 and Jun. 2011 – Deviation of Tsunami Heights on the Pacific Region

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The Aleutian earthquakes occurred on November 17. 2003 (51.40N,178.60E, Mw7.7) and June 24, 2011(52.008N,171.860W,Mw7.2),US accompanying with tsunamis. The 2003 tsunami was observed in the whole Pacific tidal stations (double-amplitude 52cm at Shemya). Semi-amplitude of the 2011tsunami was 6cm at Adak. Source area of the 2003 tsunami estimated by the inverse refraction diagram with the aftershock area, lies along the depth counter of 3000m, extending 130km located in the source area of the 1965 tsunami. The source of 20lllies 60km in the S-N direction in the 1957 tsunami source.. Judging from the author's method based on the attenuation of tsunami height with distance, magnitudes of tsunamis in 2003 and 2011 are determined to be *m=l* and *m=0*, respectively. It is well known that the Hawaiian Islands have suffered severe damage by the 1946 Aleutian tsunami, and Crescent City, California also inundated by the 1964 Alaska tsunami.

The locality of tsunami height deviation from the average tsunami magnitude is discussed for the five Aleutian-Alaska tsunamis. The deviated magnitude values in California, Chile and Hawaiian Islands are the 1-3 grades (tsunami height- 2-lo times) larger than the mean magnitude. Tsunami heights in Japan are the mean values or less. The deviated heights at each region are different from the epicenter location, because of the directivity effect.

Keywords: Aleutian-Alaska tsunamis, Tsunami magnitude, Directivity of tsunamis

Japan Geoscience Union Meeting 2012
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HDS26-12 Room:102B Time:May 21 14:00-14:15

Heights of the tsunami of the Empo Boso-Oki earthquake of November 4th, 1677

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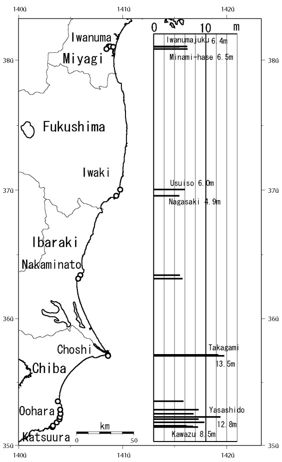
[1]none, [2]Tohoku U., [3]Pasco, [4]Pacific Consultants, [5]JNES

The tsunami height distribution of the Boso-Oki earthquake of November 4th, 1677 had been studied by Hatori(1975, 1979, and 2003), Tsuji(1994) and Takeuchi et al.(2007), but most of those results were estimated ones by their damage grade. In the present study we newly estimated tsunamiheits with considering ratio of dameges houses with total number of houses in each damaged coastal village, and we made exact measurement at all villages where description of tsunami damage was recorded in old documents. We clarified the lords who contralled each villages, and checked the configulation of residential area on the detailed map of 50,000 to one published in the period of the Meiji Era. We estimated the thickness of flooded water as 3 meters for the case that almost all houses were swept away in the residential area of a village, as 2.5 meters for the case that the number of swept away houses was about half of the total number of a village, as 2 meters for the case that the not over half of the total houses were sewpt away.

The highest inundation height of 13.5 meters heigh was measured at Takagami village in Choshi city, where sea water rushed into a pond and sea water flooded over the path whose height was 13.0 meters.

Keywords: historical earthquake, historical tsunami, Boso-oki earthquake, tsunami earthquake



Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

HDS26-13 Room:102B Time:May 21 14:15-14:30

Observation of azimuth dependence in dominant periods of the 2011 Tohoku Earthquake Tsunami

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Tide gage records of the 2011 Tohoku Earthquake Tsunami observed at tide stations around the Pacific Ocean were decomposed into the spectra. The records of twelve tide stations including Japanese two, Hanasaki and Chichijima, were downloaded from Internet sites, and after reducing the tidal level the spectra were calculated for time duration of 6 hours including the arrival time with time interval of 1 minute. From the energy density spectra dominant period was defined as a period of the maximum value. At the same time spectra of sea level oscillation at quiet sea condition observed at the same tide stations were calculated for time variation of 6 hours before the arrival to detect dominant periods based on the local topography.

As the result it proved that the tsunami brought a change of dominant period larger than 5 minutes in seven cases from those of the quiet sea condition. Generally, the displacement was generated toward an azimuth dependence predicted from the theory (Yamashita and Sato,1974), which is based on the assumption of constant sea depth. In the theory a reverse fault with low dip angle and the length of 450 km, the width of 200 km was assumed, and the spectra were estimated at the distance of 2000km. The theory predicts a variation of the dominant period for azimuth relative to the strike direction. Dominant periods of the tsunami and the seiche are shown in Figure 1 with a predicted curve of 6000m in sea depth. Thus, it is concluded that observed dominant periods showed an azimuth dependence characteristic to the radiation of faulting source.

Keywords: azimuth dependence, 2011 Tohoku Earthquake Tsunami, dominant period, tide gage records

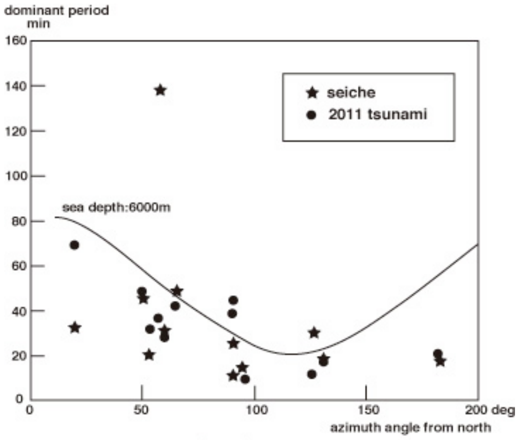

Figure 1

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HDS26-14 Room:102B Time:May 21 14:30-14:45

Origin of the reversed initial amplitude of distant tsunami

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Distant tsunami waveforms recorded at deep open sea from the 2010 Chile earthquake and the 2011 Tohoku-Oki earthquake show a reversed prolonged small initial tsunami phase arrival, which is easily identified by the reversed polarity of the large amplitude tsunami arrival following the small-amplitude initial phase arrival. The small reversed polarity before the main peak is visible in the original tidal pressure data and not introduced during the de-tide process. Thanks to the low noise DART data from large earthquakes, the arrival of the small initial phases at distant buoys are identified as early as 1 hour before the arrival of large amplitude tsunami with a reversed polarity. The small initial amplitude is as large as 10 % of the amplitude of the main phase at largest distances. Such an initial phase is not observed at buoys near the earthquakes.

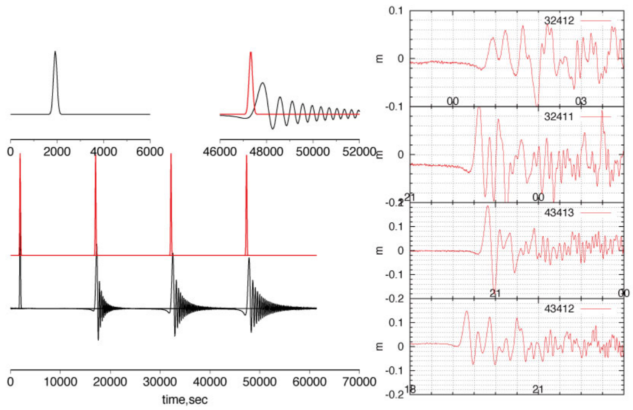
The synthetic tsunami for 1D PREM earth model including the effect of the elastic crust, mantle, and core of the earth, and the effect of the compressibility of the ocean water, and the effect of the gravity potential change caused by the motion of the mass of the water and the solid earth during the tsunami propagation, has been computed. Compared with the tsunami synthetics waveforms computed based on a conventional non-dispersive long-wavelength water waves, the tsunami for 1D earth shows a delayed arrival of the main amplitude peak of the tsunami, in addition to a prolonged small initial amplitude phase with reversed polarity before the main peak.

Two features, delayed arrival of the main amplitude peak and the small amplitude initial phase with a reversed polarity, are successfully re-produced by the tsunami computation for 1D PREM earth model.

The small initial tsunami with a reversed polarity observed at distant locations is caused by the dispersion of the long-wavelength tsunami, and should not be misinterpreted as an evidence of a precursory crustal movement prior to the large earthquakes.

Figure Left: shows synthetic tsunami waveforms of dispersed tsunami and non-dispersive tsunami. Right: observed tsunami waveform at DART buoys after the 2011 Tohoku-Oki earthquake.

Keywords: tsunami propagation, initial amplitude anomalies, Tohoku-oki earthquake, Chile earthquake, GPS wave gauge, ocean bottom pressure gauge



Japan Geoscience Union Meeting 2012
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Numerical modeling of Kamaishi offshore tsunami barrier against Tohoku earthquake tsunami

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At 14:46 local time on March 11, 2011, a magnitude 9.0 earthquake occurred off the coast of northeast Japan. This earthquake generated a tsunami that struck Japan as well as various locations around the Pacific Ocean. Based on the post-event tsunami survey, the regional and local scale analyses were conducted to understand the basic characteristics of this event. It is possible to verify the effectiveness of tsunami counter measure by this event. This study simulated tsunami inundation in Kamaishi bays targeting Kamaishi offshore wave barrier.

A series of numerical simulation was performed by quasi-three dimensional and full three dimensional (Navier-Stokes equation) model. The spatial resolution was 25-50m depends on the target and size of target area was 12 km by 10 km around Kamaishi and Ryoishi bays. The offshore boundary condition was given by GPS wave gage at offshore of Kamaishi bay.

The validation of numerical models was conducted against to post-event tsunami survey data on the land. Both numerical models slightly over predict against the survey data but they gave reasonable agreement with the data. The offshore barrier in Kamaishi bay reduced the tsunami height inside of Kamaishi bay about 30-40% in comparison with no-barrier case.

Keywords: The 2011 Tohoku Earthquake Tsunami, Kamaishi bay, Wave barrier, Numerical modeling, Velocity profile