Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-01 Room:418 Time:May 1 09:00-09:15

Magnitude of the Solomon Tsunami of February 6, 2013

HATORI, Tokutaro[1]*

[1] nome

The great earthquake occurred on February 6, 2013 at the junction of Solomon and New Hebrides trenches (10.738S, 165.138E, 28.7km depth, M8.0, USGS). Moderate tsunami was widely observed in the Pacific zone (WC/ATWC, NOAA, JMA). The tsunami killed 10 persons and 590 houses destroyed at Nendo Is.(Santa Cruz Is.) located near the source region. The estimated source lies 250km length toward E-W direction. Judging from the attenuation of tsunami height with distance, tsunami magnitude is determined to be m=2 that the grade is the mean value for earthquake magnitude. For tsunami magnitude, semi-amplitudes of the following regions are relatively large: 20cm at Crescent City, California, 18cm at Maui, Hawaii, 17-19cm in Galapagos and Coquimbo, South America and 40cm at Hachijo Is., 19cm at Chichijima ,Japan. The pattern of amplitude distribution is similar to other Solomon-Vanuatu tsunamis.

Keywords: Solomon Tsunami, Tsunami magnitude, February 6, 2013, Tsunami source, amplitude deviation

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-02 Room:418 Time:May 1 09:15-09:30

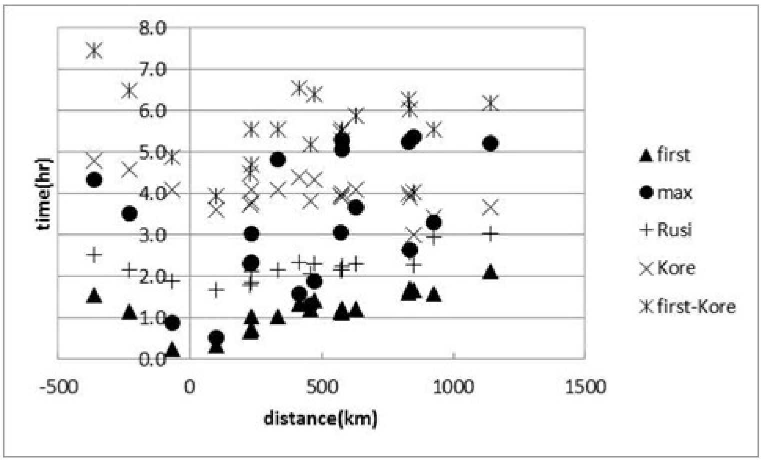
Arrival times of reflected waves and the maximum phases of tsunami?the 1993 Hokkaido Nansei-oki Tsunami

ABE, Kuniaki[1*] ; OKADA, Masami[2] ; HAYASHI, Yutaka[3]

[1]none, [2]MRI, [3]MRI

Tsunami maximum phases are frequently attained by reflected waves. Arrivals of reflected waves were studied in relation with arrivals of maximum phases. Arrival times of reflected waves are calculated from combination of refraction diagrams of direct wave and arbitral reflected wave. The arrivals are recognized in coincidence between the prediction and the observation. Under this circumstance travel times of first and maximum waves were obtained for the 1993 Hokkaido Nansei-oki Tsunami and predicted travel times of reflected wave from Russia, Korea and double reflected waves from Honshu and Korea are plotted in figure 1. As the result arrivals of maximum phases are classified into three groups. First one, the direct wave from the source, is earlier arrivals before the reflected wave from Russia. Second one is a group found between arrival times from Russia and Korea. This is recognized as reflected wave from arbitral coast of Eurasia continent. Third group is one found at arrival times shorter than those of the double reflection. This group is interpreted from double reflections from coast near the source and Korea.

Keywords: Tsunami, maximum phase, late arrival, reflected wave, 1993 Tsunami



Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-03 Room:418 Time:May 1 09:30-09:45

Quantitative comparison of the 2011 Tohoku earthquake and past tsunami heights

SATAKE, Kenji[1*] ; TSUJI, Yoshinobu[2] ; HARADA, Tomoya[3] ; ISHIBE, Takeo[1] ; NISHIYAMA, Akihito[1] ; KUSUMOTO, Satoshi[4]

[1]Earthquake Research Institute, the University of Tokyo, [2]ERI, the University of Tokyo, Now at Fukada Geological Institute, [3]CIDIR/ERI, the University of Tokyo, [4]ERI, the University of Tokyo, Now at Dia Consultants

The tsunami heights from the 2011 Tohoku earthquake were on the average 1.5 times the 1896 Meiji Sanriku tsunami, 3 times the 1933 Showa Sanriku tsunami, 4 times the 1960 Chilean tsunami, and 14 times the 2010 Chilean tsunami along the Sanriku coast. The Sanriku coast is a typical ria coast, a sawtooth-shaped irregular coastal shape, and the local variation of tsunami heights is very significant. We carefully selected the sites where the past measurement points are known, and comparisons were made at the same villages or small-scaled bays (roughly a km scale).

Along the Sanriku coast, the median value of 1896/2011 tsunami height ratio at 83 measurement points is 0.69, and a correlation coefficient is 0.34. The median 1933/2011 ratio at 94 points is 0.33 with a correlation coefficient of 0.47. The 2011 tsunami was higher along the southern Sanriku coast (Miyagi prefecture). In the central Sanriku coast (Iwate prefecture), the 2011 tsunami was 1.2 times the 1896 tsunami and 2 times the 1933 tsunami. The comparison was made at 98 points for the 1960 tsunami with a median ratio of 0.25, and at 12 points for the 2010 tsunami with a median ratio of 0.07. The correlation coefficients are lower, 0.17 and 0.14 for the 1960 and 2010 Chilean tsunamis, than the past Sanriku tsunamis. All the Sanriku tsunamis (1896, 1933 and 2011) had different earthquake source area and types, but the tsunami height distributions were similar, indicating that the tsunami heights are more sensitive to the local topography for the near-field tsunamis. The lower correlation with the Chilean tsunami may be due to the fact the dominant period of incoming tsunami was more than twice longer for the trans-Pacific tsunamis.

Comparisons with the two Chilean tsunamis were also made on the Ibaraki and Chiba coasts. The tsunami heights were compared at 24 points for the 1960 tsunami and 14 points for the 2010 tsunami. The median 1960/2011 ratio is 0.62, while the median 2010/2011 ratio is 0.28. The correlation coefficients with the 2011 tsunami heights are higher, 0.63 and 0.41 for the 1960 and 2010 Chilean tsunamis. The high correlation may be due to general decrease of tsunami heights toward south, and the fact that the tsunamis were locally high near peninsula such as Asahi city in Chiba prefecture.

We used the 2011 tsunami heights at 120 points measured and reported by Tsuji et al. (2011 BERI); the 1896 tsunami heights reported by Yamana, Iki and Matsuo, the 1933 heights by Matsuo, Kunitomi and ERI, the 1960 heights by Comm. Field Investigation and Japan Meteorological Survey, and the 2010 heights by Tsuji et al. and Imai et al. The full data and reference are given in Tsuji et al. (Pageoph in press).

Keywords: The 2011 Tohoku earthquake, tsunami, 1896 Sanriku tsunami, 1933 Sanriku tsunami, 1960 Chile tsunami, 2010 Chile tsunami

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-04 Room:418 Time:May 1 09:45-10:00

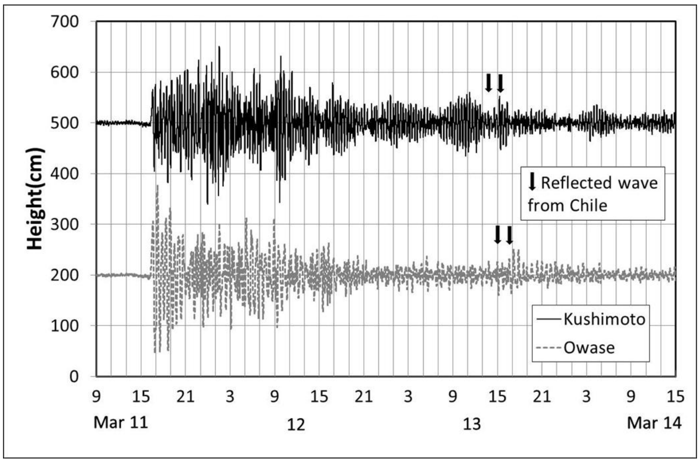
Tsunami reflected from Chilean coast and observed in Japan - the 2011 off Tohoku Tsunami

OKADA, Masami[1*] ; ABE, Kuniaki[2] ; HAYASHI, Yutaka[1]

[1]MRI, JMA, [2]None

We identified reflected waves from Chilean coast at Kushimoto and Owase tide stations in Japan on the 2011 off Tohoku Tsunami. It is based on amplitude increases at predicted travel times. The travel times were calculated by using the tide gage records of the 2011 tsunami at Talcuano in Chile and those of the 1960 Chilean Tsunami observed at Kushimoto and Owase. For the latter we noticed reflected waves from Chilean coast and obtained the travel times between Chile and Japan. Then, two phases of large amplitude of the 2011 tsunami observed at Talcuano were selected, and travel times of 46.7, 47.9 hrs for Kushimoto and of 48.1, 49.3 hrs for Owase were estimated. Amplitude increases at the predicted times were recognized in both tide stations. Waveforms and predicted travel times are shown in Fig.1. The identification is supported by amplitude increases at almost same travel times for two different tide stations.

Keywords: tsunami, Chile, Japan, reflected wave, 2011 tsunami



Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-05 Room:418 Time:May 1 10:00-10:15

Disaster Warning System in Thailand through Enterprise Engineering Perspective

LEELAWAT, Natt[1*] ; SUPPASRI, Anawat[2] ; IMAMURA, Fumihiko[2]

[1]Tokyo Institute of Technology, [2]Tohoku University

Introduction

Identify, assess and monitor disaster risks and enhance early warning has been set as one of the five priority areas of action in the Hyogo Framework for Action 2005-2015. This study is a part of our research project on disaster warning process management analysis as well as Leelawat et al. (2013).

Enterprise Engineering & DEMO

Enterprise engineering is an interdisciplinary field focusing on investigating of each aspect of the enterprise, including a business process, information flow, and organizational structure (Dietz, 2006). While most of the current modeling tools (e.g., BPMN) cannot achieve the enterprise engineering principles, *Design and Engineering Methodology for Organizations (DEMO)* (Dietz, 2006; Perinforma, 2012), an enterprise engineering and business process modeling language, has capability to demonstrate the validity of some principles (Dietz & Hoogervorst, 2012). Thus, DEMO has been selected in this study.

Data Collection

(Primary and Secondary) Data collection took place during Aug.-Dec. 2013. The face-to-face interviews with the acting Director of National Disaster Warning Center (NDWC) of Thailand and the Director of the Seismological Bureau, Thai Meteorological Department (TMD) were conducted in Sep. 2013 through the semi-structured style interviews, together with the observation.

Findings and Discussion

There are 2 main actual players in the Thai warning system as mentioned. The case has been analyzed by DEMO. According to Perinforma (2012), the *Organization Construction Diagram (OCD)* and *Transaction Product Table (TPT)* have been created to show the compact form of the system. DEMO shows its capability to express the sketch of the organization, together with some interesting issues.

First, we can understand the authority and responsibility from OCD and TPT. It can be seen that announcement decision is authorized to only NDWC (i.e., one actual warning announcer). It is a good practice because it does not create the confusion that may occur from many announcing sources.

Second, through the TPT, we can see the chain of warning message announcement, from monitoring information to seismological information. It means that the duty of declaring seismological disaster and declaring warning is separated to different actor roles which in turn increase the performance because each executor can focus on their responsibility works and increase the accuracy since the seismological information has been confirmed by the initiator.

Third, by comparing with Japanese case, it can be seen that the warning system in Japan is mainly executed by one organization (i.e., JMA) while Thai case contains 2 main organizations plus other 4 monitoring organizations regarding to the aspect of information. One reason is probably from the different government hierarchical structures which separated the expertise into each departments (in different ministries) in Thai case.

Acknowledgements

The study was supported by the ACEEES and the Risk Solutions 2013 project of Tokyo Tech. The authors would like to acknowledge Capt. Song Ekmahachai (acting Director of NDWC), Mr. Burin Wechbunthing (Director of Seismological Bureau), Prof. Junichi Iijima (Tokyo Tech), and Dr. Jing Tang for their advice and support.

References

Dietz, J. L. G. (2006). *Enterprise Ontology - Theory and Methodology*. Heidelberg: Springer-Verlag.

Dietz, J. L. G., & Hoogervorst, J. A. P. (2012). The Principles of Enterprise Engineering. In *Advances in Enterprise Engineering VI* (pp. 15-30). Heidelberg: Springer Berlin Heidelberg.

Leelawat, N., Suppasri, A., & Imamura, F. (2013). Analyzing the essence of the disaster warning system in Japan. In *Proceedings of the Second International Education Forum on Environment and Energy Science 2013*.

Perinforma, A. P. C. (2012). *The Essence of Organisation Version 1.2*. South Holland: Sapio.

Keywords: Design and Engineering Methodology for Organizations, Disaster Management, Enterprise Engineering, Thailand, Tsunami, Warning System

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-06 Room:418 Time:May 1 10:15-10:30

A methodology for near-field tsunami inundation forecasting and its application to the 2011 Tohoku tsunami

GUSMAN, Aditya[1*] ; TANIOKA, Yuichiro[1]

[1]Institute of Seismology and Volcanology, Hokkaido University

We develop a new methodology for near-field tsunami inundation forecasting (NearTIF). This method required site-specific pre-computed tsunami inundation and pre-computed tsunami waveform database. Information about tsunami source of an event is required as an input for the method to work. By this method, we will not attempt to obtain a reliable earthquake source model for an event. Instead, any available information about tsunami source such as earthquake moment magnitude, earthquake fault model, or tsunami source model will be used. After information about the tsunami source is obtained, tsunami waveforms at near-shore points can be simulated in real-time during an event. Simulating tsunami waveforms by solving the linear shallow water equation on low-resolution bathymetric data does not take long time, therefore it is suitable to be used in real-time. By using root mean square analysis, a scenario that gives the most similar tsunami waveforms in the database is selected as the best-fit site-specific scenario. Then the corresponding pre-computed tsunami inundation of the best scenario is selected as the tsunami inundation forecast.

The pre-computed tsunami database is built from thrust earthquake scenarios of simple rectangular fault models with moment magnitude ranged from Mw 8.0 to 9.0. We arrange a total of 56 reference points along the subduction zone off the east coast of Honshu, Japan as the center top of the fault planes. The points are grouped into four depth categories of shallowest, upper intermediate, lower intermediate, and deepest plate interface. The earthquake scenarios for each depth category have moment magnitude range of Mw 8.0 to 9.0, Mw 8.0 to 8.9, Mw 8.0 to 8.8, and Mw 8.0 to 8.7, respectively, from the shallowest to the deepest plate interface, making a total of 532 scenarios.

Sites are chosen based on their coastal geomorphology (i.e. bay, lagoon, isthmus) or location of coastal community. Virtual observation points at which tsunami waveforms is computed are placed strategically near-shore, around a bay at depth of deeper than 30 or 50 m depending on the bathymetry.

We test the algorithm to hindcast tsunami inundation along the Sanriku coast that was generated by the 2011 Tohoku earthquake. To produce accurate tsunami inundation map, accurate information about tsunami source is required. We used source models for the 2011 Tohoku earthquake previously estimated from GPS, W phase, or offshore tsunami waveform data. These source models could be available before tsunami hits the shore. The forecasting algorithm is capable of providing a tsunami inundation map that is similar to that obtained by numerical forward modeling, but with remarkably faster speed. Using a regular laptop computer, the time required to forecast tsunami inundation in coastal sites from the Sendai Plain to Miyako City is approximately 3 min after information about the tsunami source is obtained. We found that the tsunami inundation forecasts from the GPS (5 min), W phase (5 min and 10 min) fault models, and tsunami source model (35 min) are reliable for tsunami early warning purposes and considerably similar to the observation. This method can be used to develop a future tsunami forecasting systems with a capability of providing tsunami inundation forecasts in the near field locations.

Keywords: near-field tsunami inundation forecast, pre-computed tsunami database, tsunami early warning

HDS27-07 Room:418 Time:May 1 11:00-11:15

An offshore type of GPS tsunami meter using QZSS and ETS-VIII satellites

TERADA, Yukihiro[1*] ; HASHIMOTO, Gousei[2] ; MOTOHASHI, Osamu[2] ; YAMAMOTO, Shinichi[3] ; WADA, Akira[4] ; KATO, Teruyuki[5]

[1]Kochi National College of Technology, [2]Japan Aerospace Exploration Agency, [3]National Institute of Information and Communications Technology, [4]Hitachi Zosen Corporation, [5]The University of Tokyo

A new tsunami observation system has been developed, which employs the GPS technology to detect a tsunami before it reaches the coast. The GPS antenna attached on the top of a buoy floating at the sea surface is one of the important apparatus in this system. The estimated positions of the antenna includes not only tsunami but also all kinds of sea surface changes including wind waves, tides etc. The low pass and high pass filters are used for detection of tsunami. After a series of preliminary experimental studies, the operation-oriented experiments were conducted at two offshore sites. These results showed that a GPS buoy was useful to early detection of tsunami. And the Ministry of Land, Infrastructure, Transport and Tourism has established the GPS buoy system for monitoring sea waves with fifteen GPS buoys along the Pacific coast and Japan sea coast since the year of 2008. These system succeeded to detect the tsunami of the 2011 off the Paciffic coast of Tohoku Earthquake.

Currently, the GPS buoy system uses RTK (Real Time Kinematic) method which requires land base for precise positioning of the buoy. This limits the distance of the buoy from the coast at most 20km. There are two problems to be conquered, one is the precise GPS positioning and the other is the data transmission methods. The algorithm of PVD (Point precise Variance Detection) method and PPP-AR (Precise Point Positioning method with Ambiguity Resolution) method are successfully under examination in the Muroto GPS buoy. Also, the satellite communication system using QZSS (Quasi-Zenith Satellite System) and ETS-VIII (Engineering Test Satellite VIII) were introduced for this GPS tsunami observation system experimentally.

Keywords: QZSS, ETS-VIII, GPS Tsunami Meter, PVD, PPP-AR

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-08 Room:418 Time:May 1 11:15-11:30

Long-term deployment of Wave Glider for a real-time tsunami monitoring system using the Vector Tsunameter

HAMANO, Yozo[1*] ; SUGIOKA, Hiroko[1] ; TOH, Hiroaki[2]

[1]JAMSTEC, [2]Kyoto University

We have been developing a real-time tsunami monitoring system by using the Vector Tsunameter(VTM), in which we use an unmanned surface vehicle called Wave Glider, manufactured by Liquid Robotics Inc. The WG, equipped with both an acoustic and a satellite communication modems, can be used to transmit data messages from the VTM to shore. In order to investigate the feasibility for this type of station-keeping operation, we made a long-term deployment of the WG at sea area. We deployed the WG on September 22, 2013 at 38 14.99N, 143 35.13E, water depth = 3420.1 m. We set 6 waypoints along a circle (200m in diameter) centered at the above position, so that the WG trace the watch circle. The experiment had been continued until the WG was caught by a drift net and delivered to the Kesennuma port on December 6,2013.

The 75-days deployment of WG gives valuable information on the performance of the WG. As for the feasibility of WG for the station-keeping operation, two problems become apparent. During the experiment, the WG sporadically escaped from the watch circle and drifted away following the ambient water current, and it returned to the circle after several days of trip. Four excursions occurred during the first 50 days, and the total of the excursion period is 20 days. For monitoring slow activities such as crustal deformation, this performance is acceptable. However, some improvements are required for monitoring the short period signals such as tsunami. The other problem is the reduction of speed over water occurred after about 2 months operation. In the middle of November, the speed abruptly decreased to less than 0.5 knots and remains low until the end of the experiment.

Based on the detailed analyses of the navigation data sets and inspection of the WG, we conclude that the twist of the umbilical cable, which connects the surface float to the sub-surface glider, triggered both the excursion and the speed reduction. The small size of the watch circle and the short distance between the waypoints (about 100 m) are main cause of the twist. The short distance causes large and frequent changes of glider heading. Since the float can not follow the abrupt changes of heading, differential rotation of the glider relative to the float arises and enhances the twist of the cable. This twist of the cable increases water drag to the WG, and the stress of the cable due to the twist inhibit the rotation of the WG. These effects reduce the movability of WG, and the speed reduction start the drift of WG following the ambient current motion. The twist of the cable mainly occurs while the WG follows the path along the watch circle. On the other hand, during the excursions, glider heading is fixed and rewinding of the cable was observed. This rewinding reduces the drag force to the WG and assist the WG in returning to its home circle.

Extreme reduction of the speed is observed after 2 months of deployments. Inspection of the WG right after the recovery indicates that the propulsion system of the sub-glider had been working well until the end of the experiment, whereas the float suffered by the biofouling of eboshi-gai (goose barnacle). The biofouling seems responsible for the speed reduction, but theoretical estimate suggests that the hydrodynamic drag due to the biofouling is not sufficient to explain the observed speed reduction. The twist of the cable and the biofouling both contribute to the speed reduction. These analyses suggest larger size of the watch circle may improve or solve the present two problems of the excursion and the speed reduction.

Keywords: tsunami, tsunameter, real-time observation, seafloor observatio

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-09 Room:418 Time:May 1 11:30-11:45

Enhancement of GEONET Real-time Analysis System for Covering over Japan

YAHAGI, Toshihiro[1*] ; MIYAGAWA, Kohei[1] ; KAWAMOTO, Satoshi[1] ; OSHIMA, Kennichi[1] ; YAMAGUCHI, Kazunori[1] ; MURAMATSU, Hiroki[1] ; OHTA, Yusaku[2] ; DEMACHI, Tomotsugu[2] ; MIURA, Satoshi[2] ; HINO, Ryota[2] ; SAIDA, Yuichi[3] ; DOUKE, Yuki[3]

[1]Geospatial Information Authority of Japan, [2]Graduate School of Science, Tohoku University, [3]Hitachi Zosen Corporation

Geospatial Information Authority of Japan (GSI) has been operating a continuous GNSS observation network system, known as GEONET (GNSS Earth Observation Network System), since 1994. Currently, GEONET consists of approximately 1,300 nationwide GNSS stations and its analysis center. Each station collects GNSS data with 1Hz sampling and those data are transmitted to the analysis center in real-time. GSI offers the observation data to the public in order to support various types of public surveys in Japan and precise positioning services using GNSS.

In the field of disaster prevention or mitigation, GEONET also plays very important roles by monitoring crustal deformation occurred by such as earthquakes or volcanic activities. In addition, after the 2011 off the Pacific coast of Tohoku Earthquake (Mw9.0), it is pointed out by a governmental committee that GEONET should be utilized for tsunami early warning by offering a first realistic estimation of moment magnitude (Mw) after large earthquakes. It is based on the fact that GNSS real-time positioning generally has big advantages in estimating moment magnitude (Mw) of the large earthquakes compared to short-period seismometers in terms of avoiding underestimation problem.

Since then GSI has been developing a new GEONET real-time analysis system, named REGARD (Real-time GEONET Analysis System for Rapid Deformation Monitoring), jointly with Tohoku University. It is designed for estimating permanent displacement field and Mw of giant earthquakes and notify the results in real-time. First, the GEONET data are processed by RTKLIB ver.2.4.1 (Takasu, 2011) for real-time GNSS positioning. We adopt both 'RAPiD' technique (Ohta et al., 2012) and the Early Earthquake Warning (EEW) information (Kamigaichi et al., 2009) for automated detection process of permanent displacements. Once the displacements are detected, corresponding fault source model is immediately estimated and the system sends the results to registered addresses by e-mail.

GSI launched its prototype system in April 2012 with 143 stations covering mainly Tohoku region and also has been evaluating its performances using archived data of some past earthquakes. We verified that the system successfully could estimate appropriate Mw values just after a couple of minutes in case of large events (e.g. Mw8.9 in the 2011 Tohoku earthquake), whereas it hardly detect proper values if the size of earthquake is less than Mw7.5. Based on the results and performances of the prototype system, we upgraded REGARD in 2013 for covering all over Japan by using most GEONET stations and enhancing its redundancy by carrying out two independent processing in parallel. This new system was launched in April 2014.

We present the evaluation results of the prototype system and introduce the upgraded REGARD including future plans focusing on exploiting to tsunami warning.

Keywords: GEONET, RTK-GPS, Real-time

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-10 Room:418 Time:May 1 11:45-12:00

Tsunami inundation modeling of the 2011 Tohoku tsunami using the source estimated from the offshore tsunami records

BABA, Toshitaka[1*] ; TAKAHASHI, Narumi[1] ; KANEDA, Yoshiyuki[1]

[1]JAMSTEC

As the number of offshore tsunami stations comes up, it is becoming possible to estimate tsunami source in real time by exclusively using offshore tsunami information. The issue we would like to discuss in this study is how accurate is it in terms of coastal tsunami prediction? In order to investigate this, we performed a tsunami inundation modelling of the 2011 Tohoku tsunami and compared with the tsunami field survey. We used the Saito et al. (2011) source model inverted from the offshore tsunami waveforms alone, although it was not a real-time solution, in the numerical simulation. The nonlinear Boussinesq equations were solved for the tsunami propagation because tsunami soliton fission was observed during the 2011 tsunami, which is split short-period waves around tsunami crest caused by combination of wave nonlinearity and dispersion. We also applied a variable nested algorithm which allows the spatial resolution of the study region to be easily increased. The finest grid spacing was set to be 2/9 arcsec (about 5m). The three dimensional shape of buildings and structures from lidar measurements were directly embedded on the digital elevation model to include the effect of them on tsunami inundation. Our dispersive tsunami code (JAGURS) was fully parallelized with MPI and OpenMP libraries so that the large scale dispersive modeling could be implemented within realistic computation time. According to Aida (1978), the geometric mean K and geometric standard deviation k was used to evaluate the reproducibility of the numerical simulation. For our numerical simulation results, the K and k were calculated to be 0.97 and 1.27, respectively. These values satisfy the adequacy criteria for tsunami numerical modeling established by the Japan Society of Civil Engineers (2002) ($0.95 < K < 1.05$, $k < 1.45$). Accordingly, the present study showed the reliability of the tsunami prediction procedure that uses tsunami sources obtained with the offshore tsunami records alone.

Keywords: 2011 Tohoku tsunami, Nonlinear dispersive theory, Simulation

HDS27-11 Room:418 Time:May 1 12:00-12:15

Real-time tsunami simulation and visualization system using rapid CMT solutions in Southeast Asia

INAZU, Daisuke[1*] ; SAITO, Tatsuhiko[1] ; KUMAGAI, Hiroyuki[2] ; PULIDO, Nelson[1] ; FUKUYAMA, Eiichi[1]

[1]NIED, [2]Nagoya University

Southeast Asia, especially Indonesia and Philippines, is one of the most seismically active region in the world. NIED carries out real-time estimation of moment tensors of earthquakes and maintains a CMT catalogue in this region using the SWIFT system (Nakano et al. 2008), as well as waveform data from dense broadband regional seismic networks in Indonesia and Philippines, under a cooperative research with BMKG (Indonesia), PHIVOLCS (Philippines), and GFZ (Germany). Developing a rapid forecast/hindcast system of the tsunami is also necessary in particular for the tsunamigenic earthquakes.

We have been constructing an automated system for the tsunami simulation (Inazu et al. 2013 SSJ meeting). The current version of the system conducts simulations and visualizations of the followings procedures (1-4). The tsunami simulation is numerically carried out with a finite difference scheme from an initial condition given by a rectangular fault model.

1) Estimate a CMT solution by the SWIFT system.

2) Calculate the width, length, and slip amount of the rectangular fault model from Mw using an empirical scaling law. We here employ two scaling laws for the sake of evaluation of the uncertainties among the tsunami simulation results. Two parameters with small/large slip amount (or large/small rupture area) are then obtained for an estimated Mw.

3) Two fault mechanisms are obtained based on the double couple solutions, and then we expect four scenarios of the initial tsunami conditions. The seafloor deformation or initial tsunami condition are calculated by the Okada's (1985) theory for each scenario.

4) Carry out numerical simulations for the respective scenarios. We visualize the regional tsunami height distribution and the time series of the tsunami height at selected sites around the epicenter. The visualization is carried out in parallel to the simulation for an integral time interval. The maximum tsunami heights are displayed on a regional map and on coastal areas as well in parallel to the simulation.

We will present typical graphical outputs produced by the above procedures for several tsunami events.

Keywords: CMT, Tsunami, Rapid analysis

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-12 Room:418 Time:May 1 12:15-12:30

Proper scoring systems with definite connections to information values of tsunami warnings

HAYASHI, Yutaka[1*]

[1]Meteorological Research Institute

Necessary conditions which newly introduced method can improve forecast are, existing proper scoring system, and that the new method marks better score than the present method do. Up to now, these scoring system have never applied to tsunami warning system.

Some scoring rules being applied widely to binary forecasts in weather forecasting, such as having precipitation or not, have close connections to change of utility for users. These scores are based on assumption that all user know their cost to make counter measures (C) and loss in case of no counter measure (L). When the forecast says the event will occur, and all users are assumed to make counter measures. In addition, a simple probability density distribution of U(-C)/U(-L) is assumed for cost-loss model, where U is the utility function. In general, a score is calculated by using a targeted dataset, e.g., a fixed period of time, and frequencies: occurrence of targeted phenomena is forecasted and observed (hit: N_a), forecasted but not occurred (false alarm N_b), not forecasted but occurred (misdetection: N_c), and not forecasted and not occurred (hit: N_d). For example, equitable threat score (ETS $\equiv$ (N_a-K)/(N_a+N_b+N_c-K), where K $\equiv$ (N_a+N_b)(N_a+N_c)/(N_a+N_b+N_c+N_d)) is one of their scoring system.

In this paper, suitable scoring rules for tsunami warnings are derived by considering the characteristics of tsunami warnings and following assumptions.

(1) Scores can be defined without N_d, because counting N_d does not make sense for tsunami warning.

(2) In case of tsunami warning, users of forecasts can select actions to take a counter measure or not. In case of no warning, users do not take a counter measure. Change of utilities are U(-C) and U(-L) for taking a counter measure and for when a phenomenon happens without a counter measure, respectively.

(3) All users know the fault alarm ratio (FAR $\equiv$ N_b/(N_a+N_b)) of the warning, their utilities for each condition (U(-C), U(-L)), and then their rational decision-making choose the option so that their expectation of utility (E_x(U)) become maximum. Here, if U(-L)/U(-C) $<$FAR/(1-FAR) is satisfied, not taking a counter measure is the more reasonable decision. According to this assumption, larger the FAR is, larger the cost-loss ratio is, warning become easier to be ignored.

(4) Assuming three types of probability density functions on x=U(-C)/U(-L). a) Uniform model: f(x)=1, b) Low-cost model: f(x)=2-2x, and (c) High-cost model: f(x)=2x for the range of $0 \leq x \leq 1$.

(5) The scores are set to be proportional to the information value of the warning. Here, $\triangle$U can be calculated as the integral corresponding to each distribution of (4) and utilities of selected actions at the N_a+N_b warnings based on the rational decision-making described in (3). Besides, if there were not for warning system, users should have lose utility as much as -U(-L) at every event. Then, V $\equiv$-ΔU/((N_a+N_c)U(-L)).

Scores corresponding to models a)-c) in (4) are derived as follows.

a) V=N_a^2/(2(N_a+N_b)(N_a+N_c)). For good warning which satisfies both $N_a \gg N_b$ and $N_a \gg N_c$, the score can be approximated to V $\fallingdotseq$ CSI/2, where CSI $\equiv$ N_a/(N_a+N_b+N_c) is threat score or critical success index.

b) V=(2/3)(1-FAR)(1-M)(1+M/2), where M $\equiv$ N_c/(N_a+N_c) is missing ratio. For warnings with few misdetection which satisfies Nc $\ll$ Na, the score can be approximated to be V $\fallingdotseq$ (2/3)(1-FAR)(1-M/2).

(c) V=$(1\text{-FAR})^2$(1-M)/3.

The proper score system thus changes according to the cost-loss ratio, which have close relation to preparedness. It is necessary to choose suitable forecast method using proper scoring system which is corresponding to a social structure. In the meeting, the author would like to discuss also on the problem for the practical application of the scoring systems.

Keywords: binary forecast, cost-loss model, expected-utility theory, rational decision-making, score

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-13 Room:418 Time:May 1 12:30-12:45

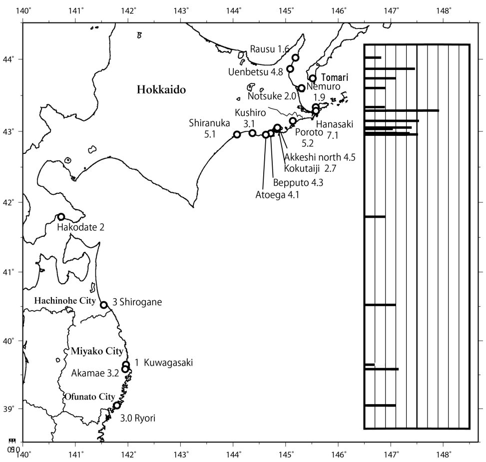
Tsunami height distribution of the 1843 Tenpo Nemuro-oki earthquake

TSUJI, Yoshinobu[1*] ; HORIE, Takehito[2] ; HASHIMOTO, Keisuke[2] ; SASAKI, Takayuki[2] ; MABUCHI, Yukio[3] ; OKADA, Kiyohiro[3] ; KUROYANAGI, Yousuke[3] ; OOIE, Takayuki[3] ; KURIMOTO, Masashi[3] ; KINAMI, Takahiro[4] ; IMAMURA, Fumihiko[5]

[1]Fukada Geolog. Inst., [2]Alpha Hydraulic Eng.Consultant, [3]Pacific Consultant, [4]Kubiki Techno., [5]IRIDeS, Tohoku Univ.

A large earthquake occurred in the sea area east offing Nenuro, Hokkaido at 6 AM, April 25, 1843 and is called Tenpo Nenuro-Oki earthquake whose magnitude is estimated at M7.5. A tsunami was accompanied with this earthquake, and hit the Pacific coast of Hokkaido and the east coast of Sanriku district, the north part of Honshu. Historical documents which record the tsunami were published by Musha (1941) and ERI, university of Tokyo(1984). It is recorded in the diary kept by a priest of Kokutaiji Temple at Akkeshi town, Kushiro district, Hokkaido that the Akkeshi branch office of the Tokugawa Government and huts of Ainu race were swept away in the residential area around the temple, and in Muko-Gishi area, north opposite coast of Akkeshi all houses were washed away and 34 Ainu people were killed. The official report written by an officer at Kushiro described that one hut and one barn were swept away at Betsufuto, about 36 kilometers east of Kushiro, and 2 houses were swept away at Atoega village. Documents written by the local meteorological observatory of Namuro described that 50 houses village were swept away at Hanasaki, about 8 kilometers south west of Nemuro Town, and survived people moved their residences to Honioi village about 6 kilometers north of Hanasaki. In this official report also it was recorded that a boy called Yamamoto Koshichi was lived on the coast of Notsuke peninsula. He experienced the tsunami there when he was 12 years old. He mentioned that the wave was divided into two waves in the offing of Notsuke coast, and the bigger wave hit the south coast of Shiretoko Peninsula. On the basis of those records, we conducted field survey for three times, and obtained the distribution of the tsunami height as the figure. The authors of the present study wish to express their thanks to JNES for its financial support in promoting our research.

Keywords: historical earthquake, historical tsunami, Hokkaido, Nemuro, Kushiro, Kuril trench



Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-14 Room:418 Time:May 1 14:15-14:30

A new calculation method for seabed displacement due to fault slip by boundary integration

AKIYAMA, Shinichi[1*] ; FUJIWARA, Hiroyuki[2] ; HASHIMOTO, Norihiko[1]

[1]CTC, [2]NIED

In tsunami simulation, initial water level of tsunami is often considered to be equal to vertical displacement of seabed generated by a source fault slip. Exact solution for displacement due to rectangular fault slip in elastic half space (Okada, 1985) has been generally applied to calculate the seabed displacement.

In order to calculate the displacement due to the source fault which has irregular form using this solution, the source fault should be modeled by patching many rectangular small faults along the irregular surface. As a result, the source-fault model has portions in which the rectangular small faults are overlapped each other or not covered the fault surface. Then, calculated displacement from the fault model is overestimated near the overlapped area or underestimated near the uncovered area. This kind of displacement discontinuity is not negligible when the fault is located near the seabed, while it is negligible in the case that it is far from the seabed. Therefore, a new technique to take the irregular form into consideration accurately is required to solve the above problem.

Under such a background, we developed a new method to calculate displacement of seabed due to slip of the source fault using boundary integration. It is well known that deformation of the medium due to a fault slip is represented by the boundary integration for the medium surface and the fault surface by applying Green's theorem to the governing equation. Considering the seabed as an elastic half space, it can also be expressed only with the boundary integration for the fault surface. Calculating the boundary integration numerically, we introduce the linear element which is used by Boundary Element Method (BEM) into the proposed method to guarantee continuity of the displacement. However the numerical integration based on Gauss quadrature formulae at the point near the fault surface is broken down by the influence of singularity of Green's function. We apply the Projection and Angular & Radial Transformation (PART) method (Hayami and Brebbia, 1988) to the proposed method to evaluate the effect of the singularity accurately. We will present formulation, validation, verification and application of this method.

This research was carried out as part of Tsunami Hazard Assessment for Japan by National Research Institute for Earth Science and Disaster Prevention (NIED).

Reference

Okada, Y. (1985) Surface deformation due to shear and tensile faults in a half-space, Bull. Seism. Soc. Am., 75, 1435-1154.

Hayami, K. and Brebbia, C.A. (1988) Quadrature methods for singular and nearly singular integrals in 3-D boundary element method, (Invited paper), Proc. 10th Int. Conf. on Boundary Elements, Southampton, Computational Mechanics Publication with Springer-Verlag, Vol. 1, pp. 237-264.

Keywords: seabed displacement, fault slip, numerical calculation, boundary integration, singularity of Green's function, PART method

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-15 Room:418 Time:May 1 14:30-14:45

Inundation hazard mapping toward probabilistic tsunami hazard assessment

SAITO, Ryu[1*] ; FUJIWARA, Hiroyuki[2] ; HIRATA, Kenji[2] ; MURASHIMA, Youichi[1] ; MURATA, Yasuhiro[1] ; INOUE, Takuya[1] ; AKIYAMA, Shinichi[3] ; ABE, Yuta[3] ; MATSUYAMA, Hisanori[4] ; TOHYAMA, Nobuhiko[4]

[1]KOKUSAI KOGYO CO., LTD. (KKC), [2]National Research Institute for Earth Science and Disaster Prevention (NIED), [3]ITOCHU Techno-Solutions Corporation (CTC), [4]OYO Corporation

A method to obtain probabilistic hazard information on tsunami run-up and inundation area is described in this study, as part of the probabilistic tsunami hazard assessment research work [NIED]. A tsunami hazard assessment has been conducted to estimate frequency of exceedance wave height at several monitoring sites along coastal region, and to be useful for the study of coastal vulnerability, based on results from a tsunami simulation with an earthquake scenario and occurrence probability. Although the main target of a tsunami hazard assessment has contributed to quantify risk in critical infrastructure facilities, inundation hazard information for urban and river regions are also important. In a study of a probabilistic tsunami hazard assessment for Japan, tsunami exceedance wave height in coastal region is probabilistically derived from numerical modelling of tsunami sources available. However, horizontal resolutions in the model is only 50 m of minimum in a land region due to computational cost constrained by tsunami simulation for Japan, which is not enough resolution to assess inundation hazard mapping on a urban area. A detailed inundation hazard assessment is expected as a result of implementing smaller grid size than 50 m.

Here we provides a technical note for estimation of inundation hazard mapping resulted from a simulation run at horizontal resolution 10 m, and show their results at Rikuzentakata, one of example. A horizontal distribution of the probabilistic inundation is calculated from hazard curves on every grid cells in inundation area. Earthquake scenarios are set by many tsunami sources and occurrence frequencies around Japan trench. An annual exceedance probability of inundation when reaching threshold is calculated from tsunami sources and occurrence probability of the earthquake scenarios. This describes the benefit of tsunami inundation hazard mapping. We could successfully show this point clearly for the first time.

Keywords: Tsunami hazard, Tsunami inundation, Probability, Hazard curve

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-16 Room:418 Time:May 1 14:45-15:00

Uncertainty for sunami hazard caused by heterogeneous slip on the characterized source model

ABE, Yuta[1*] ; HASHIMOTO, Norihiko[1] ; KORENAGA, Mariko[1] ; FUJIMOTO, Keisuke[1] ; AKIYAMA, Shinichi[1] ; FUJIWARA, Hiroyuki[2] ; HIRATA, Kenji[2]

[1]ITOCHU Techno-Solutions Corporation, [2]National Research Institute for Earth Science and Disaster Prevention

In preparation for probabilistic tsunami hazard assessment for the whole of Japan, we discuss uncertainty for tsunami heights due to a difference in slip distribution of source models.

In the process of probabilictic tsunami hazard assessment, tsunami heights at assessment points are estimated by numerical simulations. We calculate crustal deformations from source models, which are assumed as initial sea surface displacements, and then simulate tsunami propagations till tsunamis arrive in coastal sites. A simulation result changes depending on fault parameters of a source model such as magnitude, location, dip, strike, rake and slip distribution. Therefore, tsunami hazard includes uncertainties due to variability of fault parameters.

For the cases of subduction-zone earthquakes, focal mechanism is thought to be subject to a plate boundary in the characterized tsunami source model defined by probabilistic tsunami hazard assessment for the whole of Japan (Toyama et al., 2014, JpGU). On the other hand, magnitude, location and slip distribution are thought to have large varieties and their variabilities will create a large difference in tsunami height distributions. We therefore take account of the variabilities by calculating a number of source models with the different fault parameters. In this study, we give a qualitative verification for the variation in tsunami height due to slip distribution for the purpose of simplifying the hazard assessment process by using a probabilistic model for the uncertainty due to slip distribution. We examine a parameter study for several models with different slip distributions using two topography models, an uniform water depth model and a real ocean floor topography model. As the result, there is little to distinguish of geometric standard deviations between the two topography models, the values are 0.09 at a maximum.

This study was performed as a part of research for ”Tsunami hazard assessment for the whole of Japan” in NIED.

Keywords: Tsunami, Probabilistic Hazard Assessment, Characterized tsunami source model, heterogeneous slip distribution

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-17 Room:418 Time:May 1 15:00-15:15

Large slip area in characterized Tsunami source model toward Tsunami Hazard assessment

KORENAGA, Mariko[1*] ; AKIYAMA, Shinichi[1] ; ABE, Yuta[1] ; HASHIMOTO, Norihiko[1] ; HIRATA, Kenji[2] ; FUJIWARA, Hiroyuki[2] ; MATSUYAMA, Hisanori[3] ; MURASHIMA, Yoichi[4]

[1]CTC, [2]NIED, [3]OYO, [4]KKC

In previously deterministic Tsunami hazard assessment, it had been ordinary method in setting tsunami source model that it is accountable for signature of historical tsunami events. Therefore it is difficult to evaluate of tsunami risk for future events unascertained focal area or magnitude and so on. On the other hand, in probabilistic tsunami hazard assessment, it's necessary to be designed for all potentially tsunamigenic earthquakes considering target region in principle, in planning phase of modeling of elastic fault parameter (Toyama et al., 2014,JPGU). For our purpose, on setting for characterized tsunami source model for probabilistic tsunami hazard, it is essential to characterize tsunami source model and include the statistical variability. We focused on the "heterogeneous slip distribution" of tsunami source, and studied on how to setting area ratio of large slip.

According to the distribution of the fault plane slip obtained from the wave source inversion studies of the 2011 off the Pacific coast of Tohoku Earthquake (2011 Tohoku tsunami), the ratio of large slip area is said to have contributed significantly to the tsunami wave height, the ratio of the area is much the same.

Therefore, in this study, we analyzed the ratio of seismic moment by unit area regardless of the assumed size of the fault element to all mean of seismic moment. As a result from inversion models of 2011 Tohoku tsunami source and other magnitude of 9 level source, three stage characterized modeling is required, it was found that the model which accounts for 30% of the total area of 2 times the average slip, and 10% of the total area of 4 times the average slip is appropriate. And two stage characterized model for magnitude 8 level sources, its large slip (twice the average) region accounts for 30%. Comparing the maximum coast wave heights simulated using characterized model above with a detailed inversion fault model, we verified that the former covering the latter.

This study was conducted by a part of research project in NIED for tsunami hazard assessment for the whole of Japan.

Keywords: tsunami, probabilistic hazard assessment, characterized fault model, heterogeneous slip distribution

HDS27-P01 Room:Poster Time:May 1 18:15-19:30

Large tsunami remote observations from high altitude using the induced magnetic field of tsunami.

TATEHATA, Hidee[1*] ; HAMANO, Yozo[2]

[1]JMA, [2]JAMSTEC

On The 2011 off the Pacific coast of Tohoku Earthquake, massive tsunamis more than 10m attacked it in the wide range of Ibaraki from Aomori coast area. The tsunami warnings were not only sufficient but also no observation result of the tsunami, it was a big problem. The other side, at the Chichijima geomagnetic observation point had observed the tsunami induced magnetic field

As a result of example analysis for a past tsunami on Chichijima islands, the signal of the induced magnetic field was able to detect almost more than 1m tsunamis. The observation of the tsunami by the tsunami induced field has a weak point that sensitivity and a point of S/N ratio, but has a characteristic of the remote observation unlike the observation by tide gauges. If a geomagnetism sensor was installed in the hill of the Sanriku coast as a huge tsunami meter, they endured a massive tsunami and might continue observation without being destroyed.

We introduce the wave pattern of the prospective induced field of the tsunami and some character, if a sort of electromagnetic huge tsunami meter had been installed in the Sanriku coast.

Keywords: tsunami, Huge tsunami meter, induced magnetic effect

HDS27-P02 Room:Poster Time:May 1 18:15-19:30

Tsunami spectral analysis in and around Tokyo Bay

TAKIGAWA, Akira[1*] ; MUROTANI, Satoko[1] ; HEIDARZADEH, Mohammad[1] ; WU, Yifei[1] ; SATAKE, Kenji[1]

[1]Earthquake Research Institute, University of Tokyo

Coastal areas in the Kanto region have been damaged by large tsunamis in the past. The reported tsunami heights from the 1923 M7.9 Kanto earthquake show a great difference between in and around Tokyo Bay. Attenuation of tsunami heights was observed at the mouth of the bay. For example, tsunami heights were less than 1.0 m inside the bay at Shinagawa, Funabashi, and Chiba, although they were 3.0-10.0 m outside the bay (Hatori et al., 1973, ERI special publication).

On the other hand, the tsunams from the 2011 Mw 9.0 Tohoku earthquake did not experience such attenuation. For example, tsunami heights were 1.46 and 2.84 m inside the bay at Tokyo and Funabashi respectively, although they were 1.45 and 1.60 m outside the bay at Tateyama and Kyonan (Sasaki et al., 2012, CEJ).

It is important to know why this difference occurs, when estimating tsunami damage to the metropolitan area for future earthquakes. Therefore we conducted spectral analysis of tsunami waveform obtained by numerical simulations, and found that the dominant wave period in the bay is different for each earthquake. It is around 100 min for the Kanto earthquake tsunami and around 70 min for the Tohoku one. We inferred that the 100 min period may result from the normal mode of Tokyo bay (Aida, 1996, Zisin) and the 70 min period from the normal mode of Sagami Bay (Imai et al., 2011, SSJ meeting). In future, we will examine the relation between these different periods and tsunami behaviors.

Keywords: Tsunami, Spectral analysis, Tokyo Bay, 1923 Kanto earthquake, 2011 Tohoku earthquake

HDS27-P03 Room:Poster Time:May 1 18:15-19:30

Wave period dependence of the tsunami energy decay based on observation: In the case of the 2011 Tohoku-oki Earthquake

TANOBE, Atsushi[1*] ; IMAI, Kentaro[2] ; HAYASHI, Yutaka[3] ; IMAMURA, Fumihiko[2]

[1]Graduate School of Engineering, Tohoku University, [2]IRIDeS, Tohoku University, [3]Meteorological Research Institute

1. Introduction

2011 Tohoku-oki Earthquake caused serious damage. In the case of such a giant earthquake, transportation network suffer serious damage. Therefore ensuring sea route safety as the relief course is important for smooth relief and restoration activity. It is important that realize the decay process of tsunami to early ensure the security of the sea route. On the other hand, there is no clear and scientific standard to judge tsunami convergence (Hayashi et al., 2010).

In this study, we use the 2011 Tohoku-oki Earthquake tsunami wave form and show the characteristic of the tsunami decay process by the connection with time of the moving root mean square amplitude maximum onset and tsunami arrival time. And we paid attention to period, intended to clarify the characteristic of each decrement process.

2. Analysis

We targeted for analysis 20 points chose from observed tsunami wave form in the 2011 Tohoku-oki Earthquake that located in the Japanese Islands Pacific on shore and off shore station (observed by Japan Meteorological Agency, NOWPHAS, Geospatial Information Authority of Japan).

It is obvious that long sampling intervals can lead to a marked distortion of the wave properties (Rabinovich et al., 2011). We unified the sampling intervals for 30 sec and High-frequency filtering was used to remove sea level variations associated with synoptic atmospheric activity. We used the maximum of the moving root mean square amplitude to normalize the observed wave because of tsunami amplitude different from every observation point. After the Normalized process we analyzed that wave form.

Because the tsunami includes wave of various periods, and suggested decay process is different every period (Rabinovich et al., 2013). So we used band-pass 2-16 min, 16-32 min, 32-64 min, and 64-128 min filter to divide tsunami every periods. I calculated the moving root mean square amplitude and we analyzed it with a method of Hayashi et al. (2010) to define a decay coefficient.

In this study, t is the elapsed time from shock, M(t) is moving root mean square amplitude at t, Mmax is maximum of the M(t), Tm is time of onset Mmax, Tt is time of the first wave′s maximum observed, TL is differences between Tm and Tt, k is proportional constant every observation point, e is Napier's constant, τ is decay time. τ mean time required for the average amplitude being decay to 1/e .

As a result of analyzed, the tsunami decrement process of each observation point is characterized by the longer period wave that attenuate later and shorter period wave that maximum wave late for arrival.

3. Conclusion

In this study, we used the tsunami wave pattern at the 2011 Tohoku-oki Earthquake and analyzed it. I discussion a factor to characterize a decay process of the tsunami energy, and get the following result.

(1)Regardless of on shore or off shore, equilateral correlation has τ and Tt, and on shore points tends to get longer than τ.

(2)For a wider tendency, tsunamis indicates that shorter period waves attenuate much faster than longer period waves in a short period.

(3)Some observation point have a long TL about less than 32 min period.

Acknowledgments

This work was partly supported by JSPS KAKENHI Grant No.24310132.

And I gratefully acknowledge the following organizations for providing with records for the 2011 tsunami: observed by Japan Meteorological Agency, NOWPHAS, Geospatial Information Authority of Japan

Keywords: tsunami, decay, decay time, period

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-P04 Room:Poster Time:May 1 18:15-19:30

Oscillations starting immediately after the 2011 Tohoku earthquake in Japan Sea

MUROTANI, Satoko[1*] ; IWAI, Maki[2] ; SATAKE, Kenji[1]

[1]ERI, the Univ. of Tokyo, [2]Yokohama City Univ.

The tsunamis from the March 11, 2011 Tohoku earthquake were recorded in the Japan Sea. At some tide gauge stations along the Japan Sea coast of Honshu and the Russian coast, sea surface disturbances were observed immediately after the earthquake, followed by tsunami propagated through the Tsugaru Strait between Honshu and Hokkaido. Using tsunami numerical computations from seafloor displacements including the effect of the horizontal displacement and seafloor slope, the oscillations starting immediately after the origin time were reproduced. We interpret that these tsunami forerunners were generated from horizontal motion of seafloor slopes in the Japan Sea.

The tsunami forerunners were particularly remarkable at Awashima (JCG), Sado, Noto Toyama and Fukaura (JMA) tide gauge stations along the Japan Sea coast of Honshu and at Rudnaya Pristan, Preobrazhenie, and Nakhodka stations along the Russian coast of Primorye (Shevchenko et al., 2013: Pageoph). The 2011 tsunami originated in the Pacific Ocean would pass the Tsugaru Strait 1.5 hours after the earthquake. It indicates that these forerunners were different from the tsunami originated in the Pacific Ocean.

We made the tsunami numerical computation to reproduce these forerunners from seafloor displacements in the Pacific Ocean and Japan Sea. We used the source model of Satake et al. (2013, BSSA). According to Tanioka and Satake (1996, GRL), if the ocean bottom contains steep slopes or steps, the effect of the horizontal displacement of ocean bottom cannot be neglected. Computation including this effect showed the oscillations starting immediately after the origin time. However, the short-period components about a few minutes are not well reproduced. Use of finer bathymetry grid than we used (30' and 5') may better reproduce the short-period components of the Japanese tide gauge stations. Seismograms at nearby stations suggest that some of the short-period components may be the seismic ground motion. When we applied low-pass filter to the observed waveforms, the agreement between the observed and synthetic waveforms on tide gauges became better.

Because the Russian stations are about 500 km away from the source area, we also computed the synthetic tsunami waveforms from seafloor displacements computed on the spherical Earth model (Sun et al., 2009: Geophys. J. Int.). However, the computed waveforms from the spherical models are not very different from those computed on Cartesian coordinate system. It is necessary to compute the tsunami waveforms using the finer grid including the shape of the bay.

Keywords: the 2011 Tohoku earthquake, the 2011 Tohoku tsunami, Japan Sea, seafloor displacement

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-P05 Room:Poster Time:May 1 18:15-19:30

The 24 September 2013 tsunami in the Makran region, northwestern Indian Ocean

HEIDARZADEH, Mohammad[1] ; SATAKE, Kenji[1*]

[1]Earthquake Research Institute (ERI), The University of Tokyo

Tsunami waves were observed in the northwestern Indian Ocean following the Mw 7.7 Pakistan inland earthquake on 24 September 2013. We analyze eleven tide gauge records as well as one DART record of this tsunami and perform numerical modeling of tsunami. The tsunami registered a maximum wave height of 109 cm in Qurayat tide gauge station (Oman). Spectral analysis showed that the most governing period of the tsunami waves was around 12 min though wavelet analysis showed that parts of the tsunami energy were partitioned into other period bands of 7 and 16 min. Distribution of aftershocks in the region showed that all of them were located inland indicating that the tsunami was generated by submarine geological phenomena triggered by the earthquake. Tsunami backward ray tracing showed that the tsunami source was possibly located at offshore Jiwani (Pakistan) and the tsunami was most likely generated immediately after the main shock. Tsunami modeling assuming a pile-up structure at the location of the new island was not successful in reproducing the observed sea level records. A landslide source with a length of about 15-20 km, a thickness of 100-150 m located at 61.72^{o}E and 24.60^{o}N seems capable of fairly reproducing the observed sea level records. This event was the second tsunami recorded in the Makran region since 1945, and may be evidence for hazards from landslide-generated waves following seismic activities.

Keywords: Northwestern Indian Ocean, Tsunami, Makran subduction zone, Landslide, Spectral analysis, Numerical modeling

HDS27-P06 Room:Poster Time:May 1 18:15-19:30

Pre-computed Tsunami Database with Additional Slip Near to the Trench for Tsunami Early Warning in Southern Java

SUNENDAR, Haris[1*] ; TANIOKA, Yuichiro[1] ; GUSMAN, Aditya[1] ; LATIEF, Hamzah[2]

[1]Institute of Seismology and Volcanology, Hokkaido University, [2]Bandung Institute of Technology

We build tsunami database based on simple fault model scenarios for the Java trench subduction zone. We have 480 points along the subduction zone with distance between each other of 20 arc-min. This points are used as the center of simple fault model scenarios. Each point is the center of several fault models with different moment magnitudes.We used a magnitude to fault length and width scaling relationship for the fault model scenario. The moment magnitudes for the fault model scenarios are from Mw 6.3 to Mw 9.0 with interval of 0.3. The fault depth parameter is also a variable for the fault model scenario. We used depth between 10 km to 60 km with interval of 10 km.

From each fault model scenario we simulate tsunami propagation by solving the linear shallow water equations. We used bathymetry data based on Indonesian navy chart and GEBCO bathymetric dataset. The grid size for the tsunami simulation is 1 arc-min. The pre-computed maximum tsunami heights and tsunami arrival time at every point along the coast are stored in a database.

If a real earthquake occur at any location in the forecasting domain then the pre-computed tsunami heights from 16 scenarios are retrieved from the database. Theses 16 scenarios are those that are surrounding the actual hypocenter and each of the scenario has the closest higher or closest lower magnitude to the actual one. Then the tsunami heights from these scenarios are used in interpolation methods to get the tsunami height forecast. The tsunami heights from two scenarios with a same hypocenter and different moment magnitudes are interpolated by logarithmic interpolation. Then the tsunami heights with different depths and different epicenters are interpolated using linear interpolation and bilinear interpolation, respectively. The the interpolated tsunami heights is group into district administrative regions, then the maximum height for each administrative region is selected. The selected tsunami heights are categorized into three different warning levels. These levels are tsunami smaller than 0.5 m, between 0.5 m to 3 m, and larger than 3 m.

We apply this method to forecast the tsunami generated by the 1994 East Java earthquake. The 1994 earthquake is classify as a tsunami earthquake (Newman and Okal, 1998; Pollet and Kanamori, 2000). The earthquake moment magnitude was estimated to be Mw 7.6 (Abercrombie et al., 2001), Mw 7.8 (Bilek et al., 2006; USGS), Mw 7.9 (Pollet and Kanamori, 2000). Our result shows that the forecasted tsunami heights underestimate the actual tsunami heights. One of the main cause could be the fact that we used simple fault model scenarios which sizes were estimated from scaling relationship of magnitude to fault dimension of regular earthquake but not tsunami earthquake. Previous studies shows tsunami earthquake may generate large slip near the trench (Tanioka and Satake, 1996; Satake et al., 2013). Therefore to obtain a more accurate forecast, the fault model scenarios near the trench should represent fault model for tsunami earthquake event.

Keywords: pre-computed tsunami database, tsunami earthquake, tsunami early warning

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

HDS27-P07 Room:Poster Time:May 1 18:15-19:30

Simulation of tsunami inundation from future megathrust earthquake scenarios of Central Peru

MAS, Erick[1*] ; ADRIANO, Bruno[2] ; PULIDO, Nelson[3] ; KOSHIMURA, Shunichi[1]

[1]International Research Institute of Disaster Science, IRIDeS, Tohoku University, [2]Graduate School of Engineering, Tohoku University, [3]National Research Institute for Earth Science and Disaster Prevention, NIED

Great tsunami events like the 2011 Great East Japan Earthquake and Tsunami might occur around the world in the future. In particular at areas of the Pacific Rim or the Andaman Sea as history has confirmed. In this study we will focus on the central coast of Peru on the western Pacific. The earthquake history of Peru accounts for many devastating tsunami disasters in the past (1555, 1586, 1609, 1630, 1655, 1678, 1687, 1746). The potential damage to national infrastructure exposed in Callao and Lima could yield to a heavy economical breakdown in Peru. It is of great importance to assess and estimate the future tsunami inundation scenarios in order to grasp the extent of possible damage and the severity of it. Consequently, this study evaluates the tsunami hazard and the related features of inundation at the central coast areas of Peru based on possible megathrust earthquakes.

The source model we used in this study (Mw = 8.90) was obtained from results of the interseismic coupling distribution in subduction areas using GPS monitoring data as well as historical earthquake recurrence information (Pulido et al., 2011). This slip model was used to generate twelve additional slip scenarios for strong ground motion simulation, by adding spatially correlated short-wavelength slip heterogeneities (Pulido et al., 2012).

Here, we used these thirteen scenarios to evaluate the tsunami hazard of Callao area in Peru. From results of strong ground motion simulations Pulido et al. (2012) reported that the slip scenario with the deepest along strike slip average (Mw = 8.86) was the worst case scenario for strong ground motion in Lima-Callao area. On the other hand, in this study the slip model with the largest peak slip (Mw = 8.87) yielded the highest tsunami inundation and maximum velocity near shore. Such differences on maximum scenarios for peak ground acceleration and tsunami height reveals the importance of a comprehensive assessment of earthquake and tsunami hazard in order to provide plausible worst case scenarios of strong ground motion and tsunami inundation.

Acknowledgments

This study was carried out under the framework of the SATREPS project ”Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru, project sponsored by the Japan International Cooperation Agency (JICA) and the Japan Science and Technology Agency (JST). Our appreciation goes to the Ministry of Education, Culture, Sports, Science and Technology (MEXT), National Research Institute for Earth Science and Disaster Prevention (NIED) and the International Research Institute of Disaster Science (IRIDeS), Tohoku University for their support.

References

Pulido, N., Tavera, H., Aguilar, Z., Chlieh, M., Calderon, D., Sekiguchi, T., Nakai, S., and Yamazaki, F. (2012). Estimation of slip scenarios of mega-thrust earthquakes and strong motion simulations for Central Andes , Peru realizations (poster S33A-2505). In *American Geoscience Union Fall Meeting 2012*, number section III, pages 1?2, San Francisco, California, USA.

Pulido, N., Tavera, H., Perfettini, H., Chlieh, M., Aguilar, Z., Aoi, S., Nakai, S., and Yamazaki, F. (2011). Estimation of Slip Scenarios for Megathrust Earthquakes: A Case Study for Peru. In *4th IASPEI/IAEE International Symposium*, pages 1?6, Santa Barbara, CA, USA.

Keywords: megathrust earthquake, megatsunami, numerical simulation, tsunami Peru, scenarios

HDS27-P08 Room:Poster Time:May 1 18:15-19:30

Identification of submarine landslide tsunami sources: A probabilistic approach for the Gulf of Mexico

SHIGIHARA, Yoshinori[1*] ; HORRILLO, Juan[2]

[1]National Defense Academy, [2]Texas A&M University at Galveston

The devastating consequences of recent tsunami events in Indonesia (2004), Japan (2011) have changed the perception about tsunami potential and have prompted a scientific response in assessing the tsunami hazard in regions even though an apparent low-risk or/and lack of complete historical tsunami record exists. Although a great uncertainty exists regarding the return period of large-scale tsunami events in the Gulf of Mexico (GOM), geological and historical evidences indicate that the most likely tsunami hazard could come from a submarine landslide triggered by a moderate earthquake. Under these circumstances, the assessment of the tsunami hazard in the region could be better accomplished by means of a probabilistic approach to include the uncertainty in the hazard analysis and thus to identify tsunami sources.

This study aims to customize for the GOM an existing probabilistic methodology to determine landslide-tsunami sources associated with return periods. The Monte Carlo Simulation (MCS) technique is employed to determine the uncertainty related to location/water-depth and landslide dimension based on normal/lognormal distributions obtained from observed data. Along fixed transects over the continental slope of the GOM, slide angle of failure, soil properties and seismic peak horizontal accelerations (PHA) are determined by publicly available data. These parameter values are used to perform slope stability analyses in randomly generated translational submarine mass failure (SMF) obtained from the MCS technique. Once the translational SMF is identified as tsunamigenic for a given recurrence rate, a preliminary tsunami amplitude can be estimated by using empirical formulations. Thus, the annual probability of a tsunamigenic SMF is determined by the joint probability with the annual PHA.

By using the probabilistic approach we identified tsunami sources associated with return periods from few thousands to 10,000 years for each fixed transects defined over the continental slope of the GOM.

Keywords: tsunami, submarine landslide, the Monte Carlo Simulation

HDS27-P09 Room:Poster Time:May 1 18:15-19:30

A stochastic analysis and an uncertainty assessment of tsunami wave height using a random source parameter model

FUKUTANI, Yo[1*] ; SUPPASRI, Anawat[1] ; IMAMURA, Fumihiko[1]

[1]International Research Institute of Disaster Science, Tohoku University

In this paper, we conducted a stochastic tsunami hazard assessment including various uncertainties using a logic tree with targeting a region of the 3.11 Tohoku earthquake and investigated how heterogeneous slip faults generated by CRSP (Correlated Random Source Parameter) model influence the stochastic tsunami hazard assessment. In the assessment, observed tsunami wave height 6.7m in the 3.11 Tohoku Earthquake corresponded to 1112 year (0.50 fractile point), 1129 year (simple average) and 490 year (0.95 fractile point) for return period. Next, we investigated an influence that the number of slip patterns has on the results of the assessment. While the number of slip patterns had little impact on the results of the stochastic assessment in cases which a target wave height was comparatively low (2.0m), the return period at each fractile point was overestimated in case of 3 slip patterns and 5 patterns than 1 pattern when a target wave height was comparatively high (6.7m or 10.0m). We can conclude that the number of slip patterns had a great impact on the stochastic assessment depending on the target wave height. To clarify the uncertainties of tsunami wave height, we defined a 90 percent confidence interval and a coefficient of variation as indexes which can quantify the uncertainties of tsunami wave height. Basically, the 90 percent confidence interval had high value where the wave height at each fractile point was high. In addition, we confirmed that changing of maximum wave height due to changing of the asperity location in the assuming fault had a great impact on the coefficient of variations in the offshore point of the Ibaraki coast. The coefficient of variation in the offshore point of peninsula located in ria shoreline of the Iwate coast was comparatively higher than a result in closed-off section of bay located in ria coast. This result indicates an effect due to a characteristic topography in ria coast.

Keywords: probabilistic tsunami hazard assessment, uncertainty analysis, rogic tree, CRSP model