Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

STT056-P01 Room:Convention Hall Time:May 26 16:15-18:45

Numerical method of tsunami simulation including the effects of seafloor topography

Tomoya Ohata[1*], Hitoshi Mikada[1], Tada-nori Goto[1], Junichi Takekawa[1]

[1]Kyoto Univ.

Japan is surrounded by the sea and has been suffered from tsunami so often. For tsunami disaster mitigation, we should predict the arrival time and the run-up height, and we usually use numerical simulation of tsunami propagation to understand those kinds of information. Many simulations focus on the prediction of the first arrival times and the initial height of tsunami. When tsunami propagates, however, reflected waves are generated by the real change of water depth and influence the tsunami height estimation. In particular, the later phases of tsunami are strongly affected by it, and the prediction about them is difficult by conventional numerical codes. In the case of the tsunami cased by the earthquake at Kuril Islands in 2006, maximum height waves arrived at the lands a few hours after the first arrival of tsunami reached, because the tsunami waves are scattered by the Emperor Seamount Chain. To consider these phenomena, it is necessary to think of the effects of the seafloor topography on propagation of tsunami.

In this study, by introducing the seafloor topography to tsunami simulation, we express the reflected waves and think about the effects of the topography on tsunami propagation. We generate a model that allows us to calculate tsunami propagation considering seafloor topographic variation, such as a slope, on the basis of the 500m-mesh bathymetry data from JODC(Japan Oceanographic Data Center). The simulation is performed using 3 dimensional in-equally spaced grids in FDM(Finite Difference Method). By using this code, we simulate tsunami propagation over the real changes of the water depth of the sea near Japan.

We find that the simulated tsunami shows some features caused by the topography and the propagation is different from that expressed by the conventional method. We conclude that the real seafloor topography is needed to consider for practical tsunami simulation including later phases. Our results indicate that reflection, scattering, need to be accommodated in the propagation of tsunami. So the results will lead to simulate the later phases of tsunami, which is our purpose of this study. On the other hand, studying about the accuracy of the calculation is important to think about the later phases of tsunami. When the grid intervals are sparse, waves with large wave numbers cannot be calculated, and this limitation strongly affects the later phases of tsunami. We consider how the reduction of accuracy affects the expression of tsunami in this study.

Keywords: Tsunami, seafloor topography, simulation method, in-equally spaced grids, later phases of tsunami, accuracy of the calculation

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Seafloor deformation due to earthquakes with solid-fluid coupling

Nobuaki Tanaka[1*], Hitoshi Mikada[1], Tada-nori Goto[1], Junichi Takekawa[1]

[1]Kyoto University

There are many researches about the generation and propagation of tsunami based on numerical simulation. These researches, however, simulate tsunamis based on a linear long wave theory under the assumption that initial wave shape equals to the static deformation of the seafloor. The deformation of the seafloor is a function of time and space reflecting the dislocation of sub-seafloor earthquakes, and we have to consider the kinetic deformation of the seafloor for more precise simulations. In the past, Suzuki (2006) studied tunami propagation including the kinetic deformation of the seafloor caused by the dislocation of a fault, and considered the influence of solid upon liquid. His research, however, did not perfectly take the interaction between solid and liquid into account, because the deformation of solid and the analysis of liquid could not be coupled at the same time due to numerical difficulties in the simulation. We simulated the propagation of seismic wave to aim at the investigation of the displacement of seafloor considering the coupling between solid and fluid using a finite difference method.

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STT056-P03 Room:Convention Hall Time:May 26 16:15-18:45

Development of controlled-source EM survey using AUV and ROV

Tada-nori Goto[1*], Naoto Imamura[1], Hitoshi Mikada[1], Junichi Takekawa[1], Keizo Sayanagi[2], Makoto Harada[2], Takafumi Kasaya[3], Noriko Tada[3], Takao Sawa[3], Shigeo Matsuda[4]

[1]Kyoto University, [2]Tokai University, [3]JAMSTEC, [4]Clover Tech Inc.

The recent growth of world-wide requirement of metals demands advanced explorations for finding metal mine and deposits. Here we propose a new way for exploration of buried submarine massive sulphides with marine controlled-source electromagnetic technique, and magnetic survey. The result of latter suvey is introduced by Sanayagi et al. in this session. We demonstrated feasibility studies using various marine electromagnetic soundings: magnetometric resistivity (MMR) survey, CSEM survey and marine DC resistivity survey. As a result, we confirmed that the electromagnetic responses of each marine electromagnetic survey are very sensitive to the conductive layer simulating the submarine massive sulphide deposits, which is buried at the depth of several tens meters. For example, we demonstrated a CSEM survey with AUV-based source and OBEMs (ocean bottom electromagnetometers). A numerical simulation code for 2.5 dimensional electromagnetic field in the frequency domain is developed. The results shows high attenuation of received signal strength by OBEMs even with far source-receiver offset, when the source-AUV is arranged near the conductive seafloor. It implies a possibility of detection of horizontal extent of deep-sea mine. More quantitative modelling will allow the detailed sub-seafloor structure of deep-sea mine. On the basis of these numerical results, we newly developed our own controlled-source EM survey system for AUV and ROV. One of the instruments, the ROV-based marine DC resistivity survey system, was tested at a real deep-sea mine. The obtained data shows relatively conductive feature compared to the surrounding area. We confirmed a efficiency of our new CSEM survey system with ROV and AUV on imaging the distribution of exposed and buried deep-sea mine.

Keywords: deep-sea mine, controlled-source, EM survey, ROV, AUV

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Evaluation of developed precise magnetic exploration tools with using the AUV Urashima and deep-tow systems

Makoto Harada[1*], Keizo Sayanagi[1], Nobuhiro Isezaki[1], Takafumi Kasaya[2], Jun Matsuo[3], Takao Sawa[2], Hisatoshi Baba[4], Nobuhito Onishi[5]

[1]Inst. of Oceanic R&D, Tokai Univ., [2]JAMSTEC, [3]OYO International Co., [4]School of Marine Sci.&Tech. Tokai Univ., [5]Tierra Tecnica

We have developed new precise exploration tools for the seafloor hydrothermal deposits by magnetic method in order to estimate abundance of metallic resources (e.g. Sayanagi et al., 2009). Developed tools are assumed to be used with the underwater platforms such as deep-tow (DT) and autonomous underwater vehicle (AUV).

Since 2009, we have carried out several technical tests and performances by using the helicopter and research vessels. In this session, we introduce the results of the performance tests of following three research cruises.

1) Yokosuka YK09-09 Cruise (19-29 July, 2009; Kumano-Basin)

We carried out AUV Urashima and YKDT (Yokosuka Deep-Tow) dives in Kumano-nada (depth at 2,050m). To inspect the efficiency of equipments, we used a magnetic target which is consisted of 50 neodymium magnets. Four flux-gate (FG) and one Overhauser (OH) magnetometers were set up in the AUV and two FG and one OH magnetometers were used in the DT surveys (Harada et al., 2010a, 2010b). We could obtain the thee-component magnetic field and gyro data in the whole processes of AUV and DT experiments. After the effects of permanent and induced magnetization of platform were eliminated (Isezaki, 1986), magnetic anomaly generated from the magnetic target was clearly visualized.

2) Bosei-maru (Tokai Univ) Cruise (30 May - 05 Jun., 2010; Bayonnaise Knoll)

We carried out the DT survey in the inside and outside of Bayonnaise caldera (E139.75,N31.55). One FG sensor was set at the tail of the titan frame. The frame including the magnetic exploration system was towed by 50 m non-magnetized cable after the metallic wire along east-west track line at the depth between 500-550 m, which crosses just above the hydrothermal area known as Hakurei deposit.

3) Yokosuka YK10-17 Cruise (9-19 Dec., 2010; Bayonnaise Knoll)

We carried out the AUV (Urashima) surveys in the inside and outside of the Bayonnaise caldera. Three FG sensors were installed in the payload space of AUV, and one OH sensor was towed from the rear side of AUV by 25 m cable. In those dives, we used both optical fiber gyro set up in the payload space and INS (Inertial Navigation System) of AUV. The AUV was navigated at the altitude of some tens of meters and the depth of 500m to make three-dimensional models of hydrothermal deposit of Bayonnaise caldera.

From above cruises, we could understand the efficiency of our system, restrictions of navigation and their suitable operation, and the facts to be improved which are related to some kinds of noise components and combination of plural signals.

Acknowledgement:
We are grateful to the crews of R/V Yokosuka (Captains Mr. E. Ukekura in YK09-09, and Mr. K. Sameshima in YK10-17) and Bosei-maru (Captain Mr. H. Kawachi), who made our difficult trials in the navigation possible by their professional skill. We also thank to all scientific participants, marine crew, support staff, and technical experts of private companies for overall support. This project has been supported by the Ministry of Education, Culture, Sports, Science & Technology (MEXT) - Japan.

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Keywords: hydrothermal deposit, magnetic exploration, ocean bottom resources, autonomous underwater vehicle, deep-tow system, performance evaluation

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Imaging of fault structure and fresh/salt water boundary in a coastal zone by electric survey

Toshiharu Misonou[1*], Yuta Matsukuma[1], Hisafumi Asaue[1], Toru Yoshinaga[2], Katsuaki Koike[1], Jun Shimada[1]

[1]Graduate School Sci.& Tec.,Kumamoto Univ, [2]Faculty of Engineering., Kumamoto Univ.

Fault structures in coastal zones are important for disaster prevention and mitigation against large earthquakes that originate in latent fault movement in the sea areas, identification of flesh/salt water boundary, and evaluation of nutrient loads on sea environments associated with groundwater discharge. However, geological investigations in the coastal zones have not been much accumulated because of the difficulty in approaches. Then, we applied an electric survey method and using borehole data to clarify hydrogeologic structure in a coastal zone.

The Kumamoto Plain facing the Ariake Sea is well-known groundwater resource because of high mountains behind the plain such as Mt. Aso. Resistivity value is an important physical property of geologic media, which is related to porosity of rocks and soils. Chargeability is also an important electric property which is calculated from the temporal change of electric potential after stopping the current supply.

In addition to the traditional electric survey, we measured temporal resistivity change which were aimed at detecting inflow and outflow of groundwater (or seawater) in the sediments using the large difference in resistivity between seawater and groundwater. The measurements were carried out five times during 2007 to 2010 with 2D measurement lines of 150 m and 260 m lengths, using an equipments, Syscal-R2 (IRIS instrument) and multi electronode system. The measurement lines were set to be parallel and perpendicular directions to the coastal line.

By the inversion analysis of apparent resistivity and chargeability data, two fault lines along the extension of an active fault in the mountain and fresh/salt water boundary near the 20 m depth were detected from the temporal change of the resistivity. This boundary may originate from the groundwater flow along the fault line. Study area is divides into permeability zone of sand and non-permeability zone of clay. It is thought that groundwater and sea water moves along the pervious layer.

Keywords: Ariake Sea, Uto peninsula, chargeability, Resistivity

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Development and Fundamental Experiments for Validation of Transmission-type Ground Penetrating Radar

Kei Makihara[1*], Katsuaki Koike[1], Tohru Yoshinaga[2], Yoshiharu Hashino[3], Yuji Yoshida[4], Hidenori Itai[5]

[1]Graduate School Sci.& Tec.,Kumamoto Univ, [2]Faculty of Eng., Kumamoto Univ., [3]Environment & Technology Co., [4]Kyushu Keisokki Co., [5]Geochronology Japan Inc.

Visualization techniques of the subsurface structure using the electromagnetic waves have been used widely in many fields such as detecting underground pipe, investigation of existence of underground space and underground crack that can cause subsidence, excavation of archeological site, estimating geologic structure, and natural resource exploration. To improve the accuracy of visualization, estimation of subsurface physical properties such as dielectricity electric conductivity, and magnetic permeability is indispensable, which can contribute to identify the subsurface materials in addition to geometrical properties of material boundaries. However, it is difficult to estimate such subsurface properties at the present because of strong heterogeneity concerning physical properties distribution and shape of stratum boundary.

For this problem, we developed a prototype system of Ground Penetrating Radar (GPR) which separates transmission antenna and receiving antenna. A merit of this transmission-type GPR (T-GPR) is that the input signal can be received at the antenna more strongly than the traditional reflection-type GPR by reducing travel distance of radar by half.

Capability of the T-GPR was tested by a problem that it could detect caves in the ground under the water table. Simple ground model was produced using soils, water, and two types of pipes (vinyl chloride tube and Hume pipe) which were buried under the cave. These pipes were a model of actual drain pipe. Transmission antenna and receiving antenna were set on the surface and in the pipes, respectively. As the result, our T-GPR could detect the cave in the soils saturated with water regardless of the type of the pipes, which demonstrates the usefulness of T-GPR consequently.

Keywords: Ground Penetrating Radar, transmission, cave detection, drain pipe, saturated soil with groundwater

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Laboratory experiment of rock's hydraulic conductivity evaluation using EK (Electro Kinetic) phenomenon

Kenji Kubota[1*], Koichi Suzuki[1], Shinji Yamaguchi[2], Yasuyuki Hodotsuka[2], Tsutomu Ikenobe[2]

[1]CRIEPI, [2]Nihon Chikatansa

It is very important to evaluate engineering properties of rock by using geophysical exploration methods. Especially, hydraulic conductivity is one of the most important engineering properties to investigate geological structure for high level radioactive waste disposal or carbon dioxide (CO_2) geological storage. However, measurement of hydraulic conductivity requires huge consumption times. So if hydraulic conductivity is estimated by geophysical methods cost-effectively, the measurement time will be reduced.

When elastic wave is propagated into rocks, small streaming potential is generated. This is called EK (Electro Kinetic) potential, which may have a correlation with hydraulic conductivity. Hydraulic conductivity can be estimated easily by measuring the potential of rock during propagation of elastic wave.

To verify the relationship between EK potential and hydraulic conductivity, we constructed the equipments to measure the EK potential of soil and rock samples, and conducted laboratory measurements. As a result, hydraulic conductivity was related to phase delay of EK potential by the measurements of soil samples. This suggests that hydraulic conductivity can be estimated by measuring the phase delay of EK potential.

Keywords: Hydraulic conductivity, Electro Kinetic phenomenon, Geophysical Exploration, Elastic wave, Phase velocity

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Estimation of transfer function with long-period linear vibrator

Koshun Yamaoka[1*], Ryoya Ikuta[2], Toshiki Watanabe[1], Tsuyoshi Michishita[1], Shizuo Noguchi[3], Mamoru Miyakawa[4]

[1]Nagoya University, [2]Shizuoka University, [3]Kawasaki Geological Engineering Co., [4]Oya Community Development Corporation

We have made experiments on accurately controlled seismic source based on the concept of ACROSS. Conventional source that are used in ACROSS are of rotational type, in which rotation of an eccentric mass generates centrifugal force. In spite of the simplicity of the principle, the conventional source has a shortcoming that the force in lower frequency is much smaller than that in higher frequency range because the force is proportional to the square of the rotational frequency. Seismic source with linear mass motion (linear vibrator) can overcome this shortcoming, which is essential especially for the region of high scattering characteristics. We made an experiment on the linear vibrator by courtesy of Kajima Corporation in Awaji ACROSS site to compare it with the rotational type vibrator, and confirm that we can obtain transfer functions with operational method of signal processing.

Based on the result, we made the next experiment on a linear vibrator in the area of dense seismic network, which are deployed by Oya Community Development Public Corporation at Oya town, Utsunomiya city. The purposes of the experiment are 1) comparison of the result in different geological condition with that of Awaji, 2) research on the effect of subsurface vacancy to transfer function, 3) verification of velocity structure that is used in hypocenter determination by the seismic network. The vibrator was deployed in a garage of Kawasaki Coop. at the northwestern part of the network. The vibrator was operated in perpendicular directions in the frequency range of 1.0 to 10.0 Hz with an interval of 0.2 Hz. It was operated for 29 minutes for each frequency. Transfer functions are obtained by the deconvolution with the acceleration of the mass on the vibrator. Unlike the rotational ACROSS source, the linear vibrator is not synchronized to GPS. Therefore the acceleration of the mass is recorded with a data-logger whose sampling timing is synchronized to GPS.

The signal is received continuously by 126 stations that are operated by Oya seismic observatory. All the stations are located within the distance of 3km from the vibrator. Each station is deployed with a velocity sensor of vertical component with the natural frequency of 14 Hz except for 11 stations, where three component sensors are deployed. We also deployed three component sensors with a natural frequency of 2.2 Hz at 7 stations in order to compare the signal with the existing sensors. The vibration just around the vibrator is also measured. All but for 6 stations can record the vibrations above the ground noise. At the poster, the transfer functions both with radial and transverse vibrations are presented.

Keywords: control source, vibrator, ACROSS, Oya, subsurface vacancy