Potential for real-time Tsunami Monitoring using DAS Technology

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DAS (Distributed Acoustic Sensing) technology was introduced in 2011 for the demands of pipeline monitoring and intrusion detection in Oil & Gas business. The latest optical fiber sensing technology using ‘differential phase’ data now allows DAS to record seismic signal including VSP (Vertical Seismic Profiling). In addition, it has been experimenting to monitor the well production status qualitatively using flow measurements by detecting vibration noise induced by the flow. The system is called ‘hDVS’ (heterodyne Distributed Vibration Sensing).

Unlike conventional monitoring system, which usually use electro-magnetic sensor such as geophone, hydrophone and pressure gauge, hDVS uses optical fiber as vibration sensor. It measures dynamic strain of the optical fiber, either SMF (Single-Mode Fiber) or MMF (Multi-Mode Fiber) for entire length or a section defined by the user.

Conventional electro-magnetic tsunami sensors have been installed in the Pacific Ocean off the coast of Tohoku region and all over the coastline of Japan after the Tohoku earthquake and tsunami in 2011, together with seismometers. However, the measurement of the conventional sensors are point basis, while installation cost and environmental ratings of the conventional sensors limits the number and location of the sensor installations. Hence, the distance between the sensors is quite large in reality, so that the tsunami passing through between the sensors cannot be monitored.

When the Tohoku earthquake and tsunami in 2011 occurred, the expecting height of the tsunami wave when it reached the coast and the time of arrival were calculated based on the available data from limited number of tsunami sensors and the data from seismometers. There was an opinion [NHK documentary et al.] that uncertainty of such information might lead delay or misplace of the evacuation for the affected people. It is impossible to monitor and predict the behavior of a big tsunami that is beyond expectations using the data from very limited number of sensors.

In case of hDVS system, any existing ocean bottom optical fiber installations, which have been used for data transmission purpose mainly, would become line shaped flow sensor. This fact allows installation cost and time minimized. Especially, the international ocean bottom optical fiber cables were installed over the seismogenic areas where the boundaries of the plates existing, toward the seacoast of Japan straightaway. Hence, it would be possible to monitor the water flow from the seismogenic areas to the seacoast successively. Such flow data would be potential to be a certain data representing behavior of tsunami when hit. The intensity of the vibration to be increased when height of tsunami increases, therefore, the estimated height of tsunami would be able to be calculated based on the hDVS data. It was reported that several ocean bottom fiber cables were damaged by tsunamis in 2011 Tohoku earthquake, which resulted loss of optical communication, however, hDVS seismic monitoring can still be continued from the interrogator up to the damaged point.

Using hDVS technology by monitoring the development of tsunami continuously from several tens of kilometers off the coast would trigger certain tsunami warning on time, it is believed that loss of human life would be minimized from upcoming big tsunami events.

Keywords: DAS, hDVS, optical fiber, tsunami, real-time monitoring, flow

Tsunami simulations for probabilistic tsunami hazard assessment in the Japan Trench, the Nankai Trough and the Sagami Trough

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NIED began a research project regarding probabilistic tsunami hazard assessment (PTHA) for Japan (Fujiwara et al., 2013, JpGU), and gave an overview of the assessment (Hirata et al., 2014, 2015, 2016, JpGU). Also, we presented preliminary simulation results that showed tsunami height along shorelines of the Pacific Ocean where earthquake source regions along the Japan Trench, the Nankai Trough and the Sagami Trough locate (Takayama et al., 2016, JpGU; Saito et al., 2016, SSJ). Aggregating these simulation results, in this study, we discuss the tsunami height along the coastal regions. Our research target includes not only the subduction earthquakes that are mainly considered by the possible tsunami-genic earthquake derived from a seismic slip on a plate boundary in subduction zone but also unspecified fault sources such as small and medium scale earthquakes without offshore active faults. In the previous studies, Toyama et al. (2014, 2015, JpGU) and Kito et al. (2016, JpGU) introduced how to build up a set of characterized earthquake fault models (CEFMs) on hypothesized earthquakes along the Japan Trench, the Nankai Trough and the Sagami Trough, referring to the "Long-term evaluation of seismic activity for the region from the off Sanriku to the off Boso (2nd edition, 2011)", "Long-term Evaluation of earthquakes in the Nankai Trough region (2nd edition, 2013)" and "the National Seismic Hazard Maps for Japan (2014)" respectively that are published by the Headquarters for Earthquake Research Promotion (HERP). We constructed a set of the 571 CEFMs for specified earthquakes and 1319 CEFMs for the others in 40 patterns of source regions along the Japan Trench, the 3897 CEFMs for specified earthquakes and 48 CEFMs for the others in 210 patterns of source regions along the Nankai Trough, and the 135 CEFMs for specified earthquakes and 928 CEFMs for the others in 12 patterns of source regions along the Sagami Trough. Then, the total number of the CEFMs reaches about 6900. With these CEFMs, a tsunami run-up simulation estimates tsunami wave height along the pacific coast from Kagosima to Hokkaido prefectures, solved by the non-linear shallow-water equation using a leap-frog scheme. These simulations are configured by a nested grid system consisting of four sub-regions from outer 1350 m to inner 50 m in a horizontal, landward inundation keeping, and transparent at the seaward edges. Initial wave height follows vertical displacement driven by seafloor deformation via Okada's equation (Okada, 1992). The seafloor deformation consists of vertical and horizontal deformation. Toward research in the broad field of tsunami hazard we are planning to develop a database of coastal tsunami wave height provided in this study. This study was done as a part of the research project on probabilistic tsunami hazard assessment (PTHA) for Japan area by NIED.

Keywords: Tsunami hazard, Tsunami simulation, the Japan Trench, the Nankai Trough, the Sagami Trough

Integration of Probabilistic Tsunami Hazard Assessments along Japan Trench, Nankai Trough and Sagami Trough

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We have conducted a probabilistic tsunami hazard assessment (PTHA) along the Japan trench (Hirata et al., 2015), the Nankai trough (Abe et al., 2016a) and the Sagami trough (Abe et al., 2016b) with taking into account various uncertainty. By integrating the results of PTHAs along the three trenches, a risk of tsunamis occurring in the sea around Japan is comprehensively examined.
We set focal areas with conforming long-term evaluations by the Earthquake Research Committee (ERC) and make more than one earthquake fault models for each focal area to take into account uncertainty of heterogeneous slip distribution. In order to assess earthquakes which are not evaluated by ERC, we uniquely set their focal areas and earthquake fault models. For small earthquakes, we set one earthquake fault model for each focal area and assess the effect of heterogeneous slip by a probabilistic model.
We examine two kind of PTHAs for evaluating tsunami risks in different time-scale; one is “Present-time hazard” which shows a tsunami risk for 30 years out by estimating earthquake occurrence probabilities applying a renewal process based on BPT. The other is “Long-time averaged hazard” which shows a tsunami risk occurring once in thousands or tens of thousands by estimating earthquake occurrence probabilities applying a stationary Poisson process. For earthquakes which are not evaluated by ERC, we estimate their occurrence probability by applying Gutenberg-Richter law observed in each seismic region.
For integration of the three PTHA, we calculate tsunami hazard curves along the three trenches and assume the occurrence of earthquakes along each trench as probabilistically independent event.
Calculating integrated tsunami hazard curves for all coastal points and referring arbitrary tsunami heights from the tsunami hazard curves, we make tsunami hazard maps which show spatial distribution of exceedance probabilities.

Keywords: probabilistic tsunami hazard assessment, probability, long-term evaluation, tsunami analysis

Simulation of Tsunami Inundation in City Scale Model

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Objectives: The 2011 Tohoku Earthquake Tsunami showed complex behaviour of tsunami inundation over the land, especially in city areas, along the Japanese coast. The tsunami behaviour in these city urban areas was different from rural areas and indicated importance of physical roughness (e.g. buildings, houses and streets) on inundation characteristics and hydrodynamic force estimations. The purpose of this study is to understand and validate of two numerical models of tsunami inundation in the city area.

Methods: This study used quasi-three-dimensional (Q3D) model and two-dimensional (2D) nonlinear shallow water model for numerical simulation. Both models are hydrostatic model, Q3D is based on Regional Oceanic Modeling System (ROMS; Shchepetkin and McWilliams, 2005) but vertical discretization are different each other. The two different numerical models are compared to the physical experiments of Seaside, Oregon, by Park et al. (2013), which examined tsunami inundation in an idealized urban shoreline at 1/50 scale.

Results: Both 2D and Q3D model agreed well with the experimental results on the strait street from shorelines. However, the numerical models were differed from the experiment at the points behind large scale buildings. The inundation depth and velocity of the 2D simulation tended to be smaller than those of the Q3D model especially further inland. This is because the 2D model allows for larger wave energy dissipation due to a fixed vertical velocity profile and excluded turbulence and vorticity modelling.

Conclusions: The 2D and Q3D model are available to estimate the damage of the tsunami in city scale but the accuracy of inundation depends on the local reflection and diffraction due to large scale buildings. According to the comparison of Q3D model and 2D model, it is likely that the 2D model underestimates the inundation extent and local hydrodynamic forces during the tsunami inundation process.

Keywords: tsunami, quasi-3D

Transportation of sediment and heavy metal resuspended by a giant tsunami based on three dimensional, tsunami, ocean, and particle tracking coupled simulations

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The Japanese government has reported that a Nankai Trough Earthquake will occur with approximately 70 % probability within 30 years and cause a giant tsunami. Giant tsunamis can disturb marine sediment and form muddy seawater in nearshore areas. Marine sediment can be resuspended and transported by not only the tsunami current but also by the tidal, wind-forced, and density currents in the coastal ocean. Because the marine sediment in the coastal oceans around megacities contains heavy metals and cysts of harmful algae, the resuspension of marine sediments can induce multiple forms of marine pollution, such as harmful red tides and heavy metal contamination in extensive areas. This study evaluated the transportation of resuspended sediment and zinc flux from the seabed in the urban semi-enclosed sea, Osaka Bay as a pilot ocean in terms of heavy-metal pollution based on the greatest tsunamigenic earthquake scenario along the Nankai Trough occurring in the near future. The high-resolution, three-dimension tsunami-ocean coupled simulation was conducted to simulate particle tracking assuming the sediment resuspension forced by tsunami. These simulations demonstrated that the marked resuspension areas of zinc “hot spots” were locally formed in the nearshore region around landfills, and the particles from seabed from those areas vertically advected to the upper layer in the nearshore region and transported offshore owing to the estuarine circulation. After the tsunami, the zinc was transported by the tidal and wind current and widely redeposited in the bay, and gradually migrated to the southern offshore region facing Pacific through the Kitan and Kii Straight. As a result, the benthic environment and ecosystem can be improved only in areas around the “hot spots” where the zinc concentration decreases.

Keywords: Giant tsunami, Heavy metal, Particle tracking simulation, Mega-earthquake along Nankai trough , Osaka Bay

Distribution of the heights of the tsunamis of the 1707 Hoei and the 1854 Ansei-Nankai Earthquakes on the coast between Tanabe City and Kushimoto Town, Wakayama Prefecture

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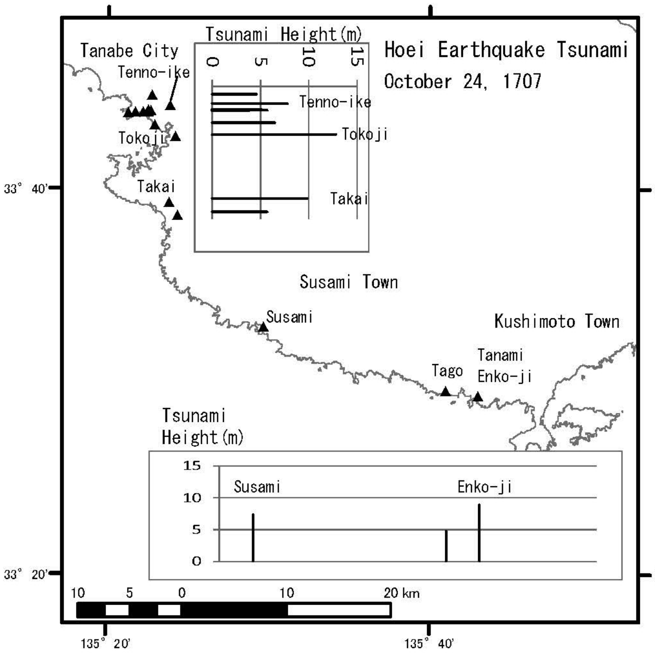
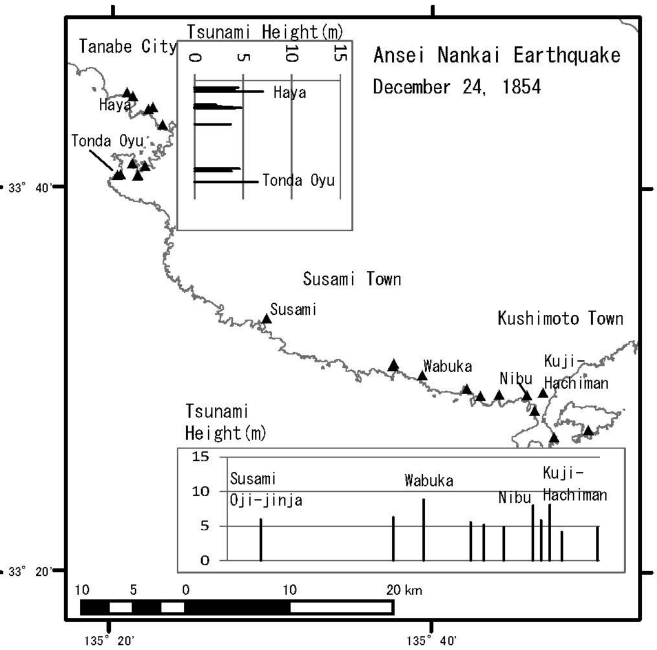
The coast between Tanabe and Kushimoto, on the west part of the Kii peninsula, was hit by huge tsunamis accompanied with an earthquake belonging to the gigantic Nankai earthquake. Many stone monuments are arranged on this coast for the victims of the 1946 Showa Nankai earthquake-Tsunami. In the Edo period (1602 to 1868 AD) two huge earthquakes were generated; one is the Hoei earthquake of 1707, and the other is the Ansei Nankai earthquake of 1854. Hatori(1980) made a field survey for estimating tsunami heights of those earthquake but his result was a rough estimation of the heights of historical earthquakes. In this study we made database of tsunami damage records on the basis of old documents which were introduced on the material books of the historical earthquakes published by Musha(1941, and 1951), and by Earthquake Research Institute (1983,1987,1989, and 1994). We conducted a field survey in the period from 17th to 20th January, 2017. The left figure shows the tsunami height distribution of the Hoei earthquake of 1707. The maximum tsunami height is recorded at a pass in front of Tokoji Temple in Shinjo area, Tanabe city, where two streams of run-up tsunami waves were jointed at the summit of the pass, where the ground height is 12.8 meters above the mean sea level. The residential area of Takai in Tonda area in Shirahama Town is located on a plateau of the height of 6.9 meters and an old document says that all houses were swept away there, which shows that the water thickness were 3.0 meters or more, so the tsunami inundation height was 9.9 meters or more. A stone monument in the cemetery of Manpukuji Temple in Susami town was made as a monument for the victims of the Hoei Tsunami in 1723 AD. On this stone monument it is recorded that the total number of the victims of the Hoei tsunami was 134 in this town.

Acknowledgement: This study was achieved as a part of the commissioned research named “Study on the historical tsunamis in the Pacific coast of Japan (2016)” on disaster prevention for nuclear facilities proposed by the Nuclear Regulation Authority, Japan.

Keywords: Hoei Earthquake-Tsunami, Ansei Nankai Earthquake-Tsunami, Historical earthquakes, Tsunami disaster


Tsunami Height(m)
0 5 10 15
Hoei Earthquake Tsunami
October 24, 1707
Tanabe City
Tenno-ike
Tokoji
Takai
33° 40'
Susami Town
Susami
Kushimoto Town
Tago
Tanami
Enko-ji
Tsunami
Height(m)
15
10
5
0
Susami
Enko-ji
33° 20'
10 5 0 10 20 km
135° 20'
135° 40'


Tsunami Height(m)
0 5 10 15
Ansei Nankai Earthquake
December 24, 1854
Tanabe City
Haya
Tonda Oyu
33° 40'
Susami Town
Susami
Kushimoto Town
Wabuka
Nibu
Kuji-
Hachiman
Tsunami
Height(m)
15
10
5
0
Susami
Oji-jinja
Wabuka
Nibu
Kuji-
Hachiman
33° 20'
10 5 0 10 20 km
135° 20'
135° 40'

A Characterized Fault Model estimated from the Tsunami height of the 2003 Tokachi-oki earthquake

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1. Purpose

NIED (National Research Institute for Earth Science and Disaster Prevention) has been conducting the project on the probabilistic tsunami hazard assessment along the coastline in Japan (Fujiwara et al., 2013, JpGU). We have already constructed characterized fault models and conducted probabilistic tsunami hazard assessment using the tsunami heights estimated by tsunami simulations along the Japan trench, Nankai trough and Sagami trough. We are currently conducting probabilistic tsunami hazard assessment along the Kuril trench. To carry out such an assessment, the framework of characterized fault models is needed to be effective. This can be verified if we confirm that a tuned characterized fault model reasonably reproduces the tsunami trace heights of historical earthquakes. To verify the validity and effectiveness of characterized fault models along the Kuril trench, we construct characterized fault models to reasonably explain the tsunami trace heights of the 2003 Tokachi-oki earthquake based on the tsunami receipt issued by the Headquarters for Earthquake Research Promotion (2017).

2. Method

Element faults with approximately 5km in length and 5km in width are configured on the surface of the Pacific plate beneath the Kuril trench to take account of fault slip on the curved surface of the subducting plate. The slip angle of each element fault is determined based on the direction of the relative motion between the Pacific plate and the North American plate. The source area is determined by delineating the source area of the 2003 Tokachi-oki earthquake shown in the long-term evaluation by the Headquarters for Earthquake Research Promotion (2004). A large slip area with 2 times of average slip amount is placed within the source area. The moment magnitude of fault models is assumed to be Mw8.3 according to the long-term evaluation, and the average slip amount was calculated using the corresponding seismic moment. These fault parameters are fixed, and the location, the aspect ratio and the area ratio of the large slip area are assumed to be unknown parameters, which are defined by the followings.

1. 3 large slip areas along the trench and 3 other ones in the direction perpendicular to the trench are placed around the area where relatively large slip of the 2003 Tokachi-oki earthquake is estimated by Tanioka et al.(2004) and Yamanaka and Kikuchi (2003).
2. The aspect ratios of the large slip areas are set to 0.9, 1.0 and 1.1 based on the slip distribution of the 2003 Tokachi-oki earthquake estimated by Tanioka et al.(2004) and Yamanaka and Kikuchi (2003).
3. The area ratios of the large slip areas with respect to the source area are set to 25%, 30% and 35% based on the slip distribution of the 2003 Tokachi-oki earthquake estimated by Tanioka et al.(2004) and Yamanaka and Kikuchi (2003).

Forward modeling is performed for the 81 characterized fault models in total.

3. Evaluation of the reproducibility of the models

The residual sum of squares is used to evaluate the reproducibility of the models. The tsunami height data of the 2003 Tokachi-oki earthquake were obtained from Japan Tsunami Trace database (Tohoku University, http://irides.tohoku.ac.jp/ project/tsunami-db.html) and selected according to Korenaga et al. (2013). The model with the smallest residual sum of squares is located at the western edge of the source area. The area ratio of the large slip area of the selected model is 25% and the aspect ratio is 0.9. The geometric average K and geometric standard deviation κ for the selected model are estimated to be 0.98 and 1.48, respectively. The selected model is considered to be a characterized fault model to reasonably explain the tsunami trace heights of the 2003 Tokachi-oki earthquake. To verify the effectiveness of characterized fault models, we are planning to construct characterized fault models to reproduce tsunami trace heights of historical earthquakes in the various regions around Japan.

This study is conducted as a part of the research project "Research on the hazard risk assessment for natural disaster" at NIED.

Keywords: 2003 Tokachi-oki earthquake, Characterized fault model, Long-term evaluation

Observation of Coupled Seiche System in Ise Bay and Mikawa Bay by HF Radar

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The tsunami waves and the seiches generated by the “The 2011 off the Pacific coast of Tohoku Earth quake” were observed by the oceanographic radars in Ise Bay and Mikawa Bay. In the present circumstances, stationary measurements on coastal region and offshore region are main streams for tsunami measurement. These can only observe just one point on oceans. However, oceanographic radars can measure current velocities widely as well as the velocities generated by tsunami arrivals and natural oscillations. Thus, it is significantly useful tool for tsunami prevention system. The seiches are bay or harbor resonant oscillations in an enclosed basin, which are generated by direct external force from open ocean such as tsunamis. These produce anomalous tide level and swift currents. Thus, the observation of seiches is of extreme importance for the disaster prevention around the coastal regions.
We used the data observed by each two oceanographic radars installed in Nabeta (NABE) and Tsumatsuzaka (MATU) in Ise Bay, and MITO and MAGUSA in Mikawa Bay. We also examined the data obtained by tide gauge records to compare the effect of tsunami with the radar observations. To analyze the total velocity of the currents generated by the seiche, we used an Empirical Orthogonal Function (EOF). To verify the physical property of the results of the EOF analysis, we calculated the natural oscillation modes by the numerical model proposed by Loomis. The results of EOF analysis showed that the oscillation modes of 120-140 and 60-80 minutes period bands were distributed widely, whereas the oscillation mode of 30-40 minutes period band was distributed locally in Ise Bay. The EOF spatial patterns of each period were good agreement with numerical models.
At the time of the arrival of the tsunami, the sea surface height of the inner part of Mikawa Bay and Ise Bay oscillated alternately. Because Mikawa bay is coupled with Ise Bay on the entrance of the bay, there are some oscillations such as two simple coupled pendulums connected by a spring. In addition to the oscillation modes of Ise Bay, we will show the pendulum system in detail.

Keywords: Seiche, Ise Bay, HF Radar

Analysis of the November 2016 Fukushima tsunami using the slip distribution of the seismic source process analysis

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An earthquake of Mw 6.9 occurred off Fukushima Prefecture on November 22, 2016. Tsunami was observed in a wide area from Hokkaido to Wakayama, especially tsunami amplitude of 1.4m was measured at Sendai port tide gage station (JMA, 2016).
In this study, the results of the seismic source process analysis are used for the evaluation of the tsunami. First, the slip distribution on the small fault is obtained by the source process analysis. After that, the crustal deformation of the seabed surface due to each fault is calculated. The crustal deformation is given as sea level, and the tsunami is calculated. Here, it is assumed that the sea level is instantaneously given at the occurrence time of the earthquake. The mesh size of the ocean bottom topography data is set to 50 m at the minimum. The seismic moments due to the small faults are added together, and Mw is 7.2 (when the rigidity μ= 30GPa) and Mw 7.0 (μ = 15 GPa).
The coastal tsunami waveform obtained by calculation well demonstrated the shape and amplitude of the short period waves of the observed tsunami. To adjust the phases of the first wave and the reflected wave obtained by the calculation to that of the observation, the initial water level was translated in the southwest direction. As a result, the wave source of the tsunami became closer to the aftershock distribution, and it gave a result that very well matches the coastal tsunami observation record.
Furthermore, we investigated what would happen if a fault that fits the optimum initial water level is given by a single uniform fault. As a result of preliminary, it was found that it was necessary to set a fault which was considerably out of the scaling law of Mw 6.9, the fault length was 20 km, the width was 15 km, and the slip amount was 6.3 m. Here, the rigidity ratio was assumed to be 15 GPa. Such a large amount of slip appears locally in the slip distribution of the seismic source process analysis and it is considered to be within a reasonable range.
In case of an earthquake deviating from the scaling law of the fault size and slip amount due to magnitude like this time, the information of the wave source of the tsunami by the source process analysis is effective. In addition, when analyzing immediately, in order to deal with the uncertainty of the horizontal position, it is conceivable that a plurality of calculations allowing some error in the grid search are performed and the result is taken out.
Acknowledgment: TUNAMI-N2 was used for tsunami numerical analysis.

Keywords: November 2016 Fukushima tsunami, source process analysis

The Development of Volume Flux Method and the Application on the 1661 Luermen event

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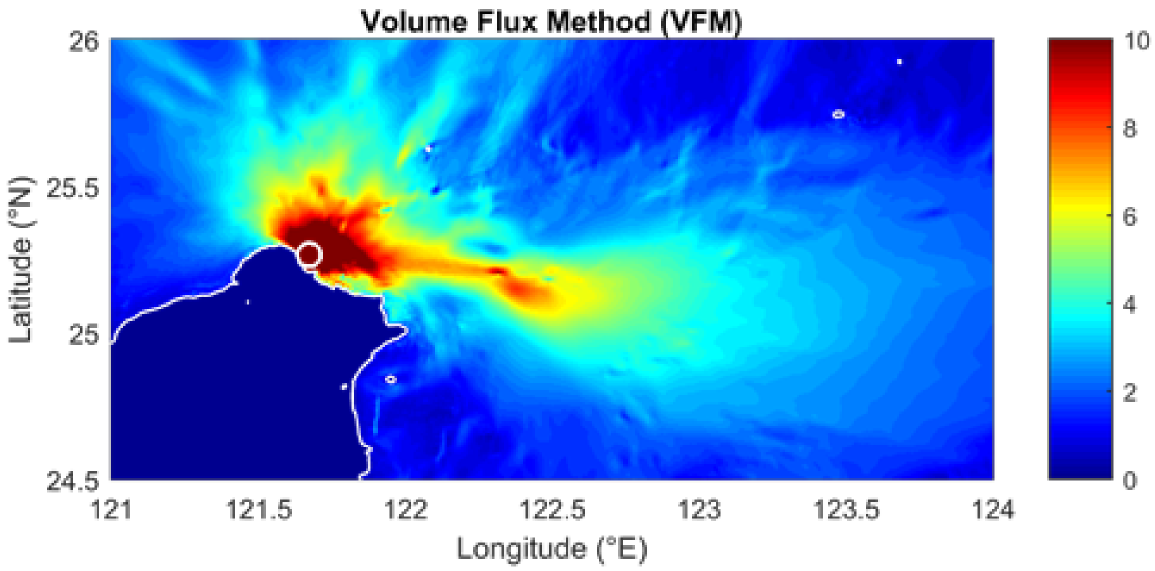
In 1661, Chinese navy led by General Koxinga at the end of Ming Dynasty had a naval battle against the Netherlands. This battle was not only the first official sea warfare that China confronted the Western world, but also the only naval battle won by Chinese Navy so far. This case was significant because it altered the fate of Taiwan until today. Ace of the critical points that General Zheng won the battle was entering Lakjemuyse bay unexpected. Luermen bay was and is an extremely shallow bay with a 2.1m maximum water depth during the high tide, which was not possible for a fleet of 20,000 marines to cross. Hence, no defense was deployed from the Netherlands side. However, plenty of historical literatures mentioned a strange phenomenon that helped Chinese warships entered the Luermen bay, the rise of water level. In this study, we will discuss the possible causes that might rise the water level, e.g. Tsunami, storm surge, and high tide. We analyzed it based on the knowledge of hydrodynamics. We performed the newly developed Volume Flux Method (VFM) for finding the potential tsunami sources, and the COMCOT tsunami model was adopted for the nonlinear scenario simulations, associated with the high resolution bathymetry data. Both earthquake and mudslide tsunamis were inspected. Other than that, we also collected the information of tide and weather for identifying the effects from high tide and storm surge. After the thorough study, a scenario that satisfies most of the descriptions in the historical literatures will be presented. The results will explain the cause of mysterious event that changed the destiny of Taiwan.

Keywords: Mudslide Tsunami, Storm Suge, volume flux method (VFM), COMCOT, 1661 Luermen naval battle


Volume Flux Method (VFM)
26
25.5
25
24.5
Latitude (°N)
121
121.5
122
122.5
123
123.5
124
Longitude (°E)
10
8
6
4
2
0

Processing Real Time Tsunami Potential of Earthquakes using Early-est

*Mehmet YILMAZER[1], Fatih TURHAN[1], Ocal NECMIOGLU[1], Aysegul KOSEOGLU[1]

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In this study current status and results of the Processing Real Time Tsunami Potential of Earthquakes Project (Supported by the Research Fund of the Bogazici University, PN12002) will be presented. Bogazici University - Kandilli Observatory and Earthquake Research Institute –Regional Earthquake and Tsunami Monitoring Center (KOERI-RETMC) is providing tsunami-warning services in the Eastern Mediterranean, Aegean and Black Seas since 1 July 2012 and has been accredited as a Tsunami Service Provider of ICG/NEAMTWS at its 13th session during 26-28 September 2016 in Bucharest, Romania. The main purpose of the this project is evaluation of usefulness of the Early-Est method (Lomax and Michelini) by the RETMC for the rapid and robust assessment of the tsunami potential of an earthquake for early warning and emergency response depending both on moment magnitude and rupture duration of the earthquake based on T_dT_0 and $T_dT_{50}E_x$ discriminants. Both real time data and the off-line earthquake waveform data are being processed using Early-est software package. In the initial phase of the project, the waveform data belonging earthquakes that have M6.5 available from all over the world are being archived and processed. So far, approximately 1000 events have been processed and prepared for statistical analysis. Next step would be the analysis of the relation between theoretical assumptions and processing results in terms of moment magnitude and tsunami potential. At the end of the study, performance of the method will be investigated using real time processing results are collected during the project period. We would like to thank Dr. Anthony Lomax for his cooperation and support in the operationalization of Early-Est in RETMC.

Keywords: Tsunami, Rupture Duration, Early-Est, Tsunami Potential Discriminant

Beamforming detection of possible tsunami forerunners at the Korean coast

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Korea is mostly surrounded by sea and the west and south offshore have shallow depth which is 51 m and 71 m of the average depth respectively. The eastern sea of Korea has relatively deeper average depth (about 1,497 m) as well as it increases rapidly along the coast, so the sea between the eastern Korean Peninsula and the Japanese Arc is such as a huge bath. When the 2011 Tohoku earthquake occurred, it not only generated a devastating tsunami in the Sanriku region, but also caused small waves in the back-arc region of Japan. They were recorded at several tidal gauges along the coast of the East Sea (Japan Sea) (e.g. Shevchenko et al., 2014; Murotani et al., 2015), and Murotani et al. referred to them as “tsunami forerunner”. The Nankai Trough, which is located to the southeast of Japan, is one of the regions capable of producing a large M9 earthquake in the future (Parsons et al. 2012). Therefore, there is a reason to believe that a potential earthquake may cause sea waves originating in southeastern Japan to reach the Korean Peninsula. In this study, we explore whether a large Nankai earthquake will produce a tsunami forerunner in the back-arc region of Japan observable on the Korean coast. We conducted a numerical tsunami simulation to obtain synthetic waveforms using a 1707 Hoei earthquake model proposed by Furumura et al. (2011). We created two virtual arrays, AR01 and AR02, to obtain synthetic waveforms. Array AR01 is located to the southeast of Korea to detect the tsunami forerunner and array AR02 is between southern Korea and Kyushu Island to record the main tsunami coming from the Nankai Trough. We then used beamforming analysis to verify the direction of tsunami arrivals using simulated waveforms at the two arrays. We determine the direction of a tsunami forerunner using waveforms from array AR01. Because the wave front of the tsunami forerunner is parallel to the array, waves generated in the northwest region of Japan show a back-azimuth angle that points in the north and north-northwestern directions. The distribution of beam-energy at array AR02 clearly shows that the main tsunami generated in the Nankai trough comes from the southeast. The beam-forming technique using tsunami waveforms is not able to accurately determine the direction of tsunami forerunner arrivals because the amplitude of the waves is small and the region has strongly varying bathymetry.

Keywords: tsunami, beamforming detection, Korean coast

