2022
Oct. 31- Nov. 4

Taiwan-Japan-New Zealand Workshop on Earthquake Hazard

臺灣-日本-紐西蘭 地震災害評估研討會

大會手冊 PROGRAM

Website QRcode

台東縣鹿野鄉鹿鳴温泉酒店
Luminous Hot Spring Resort, Luyeh, Taitung County, Taiwan

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General Information

▶ Conference Venue:

- Luminous Hot Spring Resort, Luyeh, Taitung County, Taiwan
- Contact (Tel): +886 08 955 0888
- Website: http://www.lmresort.com.tw/

▶ Shuttle Information:

- Service Provider: Luminous Hot Spring Resort, Luyeh, Taitung County, Taiwan
- Reservation number: +886 08 955 0888
- Pick Up Time: 8:00 – 18:00
- Fare:
  - ★ Luyeh Station to Luminous Hot Spring Resort (free of charge)
  - ★ Taitung Station to Luminous Hot Spring Resort (TWD 200 per ride)
  - ★ Taitung Airport to Luminous Hot Spring Resort (TWD 200 per ride)

(If attendee needs this service, please reserve in advance. This service will not be provided in the day of conference without prior reservation.)

▶ About Oral Presentations:

- Please upload your slides by USB device or cloud drive before session starts.
- Each presenter has 15 minutes including Q&A.
- Staff will ring once at 12 minutes once, and twice at 14 minutes.
  Please conclude your talk when it rings three times at 15 minutes.

▶ About Poster Presentations:

- Poster layout: Portrait (A0) (Width: 841 mm; Length: 1189 mm)
- Exhibition time: 12:30, October 31 – 12:00, November 2
- There are some adhesive tapes on site, presenters can attach their own posters with the poster codes before 12:30 on Oct. 31.
- Presenters need to remove their own posters after exhibition at 12:00 on Nov. 2.

▶ Meals Information:

- Breakfast: 7:00-10:00 in Buffet room (Oct. 31, Nov. 1, Nov. 2)
- Coffee break: 10:20-10:40 and 14:30-14:50 in Conference Venue (Oct. 31, Nov. 1)
  10:30-11:00 in Conference Venue (Nov. 2)
- Lunch: 12:00-13:30 Lunch box in Conference Venue (Oct. 31, Nov. 1)
  12:00 in Banquet room (Nov. 2)
- Dinner: 18:30-20:30 in Banquet room (Oct. 30)
  18:00-20:00 in Banquet room (Oct. 31)
  18:00-20:00 in Buffet room (Nov. 1)

▶ Floor Plan:

Sunday, October 30

12:00	**Assembling at Taipei Main Station**	
12:45-15:47	Transportation	Route
	Tze-Chiang Limited Express (3000)	Taipei Main station to Yuli Station
16:00-16:30	**Observing Fault Ruptures in Yuli Town**	
16:30-17:30	Transportation	Route
	Shuttle Bus	Yuli Town to Luminous Hot Spring Resort
17:00-18:30	**Registration**	
18:30-20:30	**Dinner (Banquet room)**	

Monday, October 31

9:00-9:05	**Opening and Welcome**	
9:05	**Session III: Geodetic Strain** **Chairs: J. Bruce H. Shyu, Andy Nicol**	
	Presenter	Presentation Title
9:05-9:20	Shih-Han Hsiao (National Cheng Kung University, Taiwan)	Scenario Ground Motion and Coseismic Displacement Inferred from the Interseismic Velocity Field
9:20-9:35	Yogendra Sharma (National Cheng Kung University, Taiwan)	Present-day Crustal Deformation along the Nainital Himalaya: Role of Garampani-Kathgodam Fault
9:35-9:50	Satrio Muhammad Alif (National Cheng Kung University, Taiwan)	Preliminary Results of Earthquake Potential Estimation in Southern Sumatra, Indonesia Using GNSS Observations
9:50	**Session IV: Sub-surface Structure Mapping** **Chairs: J. Bruce H. Shyu, Andy Nicol**	
	Presenter	Presentation Title
9:50-10:05 (Virtual)	Andrew Howell (University of Canterbury, New Zealand)	Towards an Automated Workflow for the Creation of Complex 3D Fault Models
10:05-10:20	**Discussion**	
10:20-10:40	**Coffee Break**	
10:40	**Session V: Ground Motion Prediction** **Chairs: J. Bruce H. Shyu, Andy Nicol**	
	Presenter	Presentation Title
10:40-10:55	Chun-Hsiang Kuo (National Central University, Taiwan)	Investigation of Shallow S-wave Velocity Structure and Site Response Parameters in Taiwan by Using High-density Microtremor Measurements
10:55-11:10 (Virtual)	Chih-Hsuan Sung (UC Berkeley, U.S.A)	Non-Ergodic Ground-Motion Model for Taiwan Subduction Earthquakes Based on 3-D Simulations
11:10-11:25 (Virtual)	Hongjun Si (Seismological Research Institute Inc., Japan)	Summary of the SMK NGA-Sub Ground-motion Model for Subduction Earthquakes
11:25-11:40 (Virtual)	Asako Iwaki (National Research Institute for Disaster Resilience, Japan)	Comparison of Ground-Motion Models Based on the Strong Motion Database in Japan
11:40-12:00	**Discussion**	
12:00-13:30	**Lunch**	

13:30	**Session VI: Earthquake Scenario Simulation (Part 1)** **Chairs: Kuo-Fong Ma, Ken Xiansheng Hao**	
	Presenter	Presentation Title
13:30-13:45	Caroline Holden (SeismoCity Ltd, New Zealand)	High-frequency Ground-shaking Simulations for Alpine Fault Earthquake Scenarios
13:45-14:00	Yin-Tung Yen (Sinotech Engineering Consultants Inc., Taiwan)	Scenario-based Ground Motion Simulation on Practical Application in Seismic Mitigation for Hsincheng Fault in Taiwan
14:00-14:15	Ming-Che Hsieh (National Central University, Taiwan)	Quantitative Assessing the Variability of Earthquake-source Models to Ground Motion Prediction: A Case Study in the Ryukyu Subduction Zone
14:15	**Session VIII: Seismic Risk Analysis** **Chairs: Kuo-Fong Ma, Ken Xiansheng Hao**	
	Presenter	Presentation Title
14:15-14:30	Wen-Tzong Liang (Academia Sinica, Taiwan)	Extracting Building Response from the Low-cost QSIS Seismic Network (QSN) for Structure Integrity Monitoring
14:30-14:50	**Coffee Break**	
14:50	**Session VI: Earthquake Scenario Simulation (Part 2)** **Chairs: Kuo-Fong Ma, Ken Xiansheng Hao**	
	Presenter	Presentation Title
14:50-15:05 (Virtual)	Takahiro Maeda (National Research Institute for Disaster Resilience, Japan)	Long-duration Ground Motion Simulation Using a Smoothing Scheme with a Diffusionized Wave Equation
15:05-15:20 (Virtual)	Anna Kaiser (GNS Science, New Zealand)	Rapid Characterisation of Earthquakes & Tsunami (R-CET Programme) – The Local Earthquake Challenge
15:20-16:30	**Discussion and Poster**	
18:00-20:00	**Dinner (Banquet room)**	

Session III

Geodetic Strain

Scenario Ground Motion and Coseismic Displacement Inferred from the Interseismic Velocity Field

Shih-Han Hsiao[1], Kuo-En Ching[1], Yin-Tung Yen[2], Chun-Te Chen[2], Wu-Lung Chang[3], Yi-Jui Lee[2], Ray Y. Chuang[4], and Chien-Liang Chen[5]

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[4] Department of Geography, National Taiwan University, Taiwan

[5] Central Geological Survey, MOEA, Taiwan

Based on geodetic data analysis, the interseismic velocity field could be estimated and subsequently used to evaluate the earthquake potential and the seismic hazard map. However, how to improve the seismic hazard assessment using the interseismic velocities? In this study, we took SW Taiwan as the example to answer the problem. We first estimated the horizontal and vertical velocity fields using the geodetic data from 572 continuous GNSS stations, 798 campaign GNSS data and 29 precise leveling routes between 2002 and 2021, which were collected by Central Geological Survey of Taiwan. The comparison of horizontal and vertical velocity gradients along the selected velocity profiles across the active faults in SW Taiwan implies that active fault is not the only source to affect the surface deformation pattern. Based on the 2D dislocation modeling results, the opening-mode dislocations are also needed to accommodate the surface velocities in SW Taiwan. Considering the geological features in SW Taiwan, we proposed these opening-mode dislocations as mud diapirs/mobile shales, generating the anelastic surface deformation. Then, the optimized fault geometry parameters derived from 2D models were adopted to calculate the distribution of slip deficit rates on the active faults using the 3D fault model, Baseline Inversion. The distribution of slip deficit rates on the faults represents the coupled patches during the interseismic period. In other words, these coupled patches would be the asperities in the future earthquakes. Therefore, the scenario ground motions in SW Taiwan could be not only predicted using the ground motion prediction equations (GMPEs) but also improved through our derived asperities. Moreover, we also estimated the scenario coseismic displacements using the 3D dislocation model to reveal the seismic hazard caused by permanent surface deformation in SW Taiwan.

Keywords: interseismic velocity field, scenario ground motion, scenario coseismic displacements, seismic hazard assessment

Present-day Crustal Deformation along the Nainital Himalaya: Role of Garampani-Kathgodam Fault

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Nainital region in the Kumaon division along the Northwest Himalaya falls in Zone IV of the Earthquake Zoning Map of India. Nainital Himalaya contains tectonically active fragile mountains together with a fast pace of urbanization which has enhanced the vulnerability of the area. We analyze geodetically estimated inter-seismic deformation along the Nainital Himalaya to infer the role of the Garampani-Kathgodam fault (G-KF) in present-day crustal deformation. The G-KF is an NNW trending right-lateral strike-slip fault, which intersects two major thrust faults of the Himalayan orogeny, the Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT). Thus, the fault kinematics of G-KF is essential to describing the regional deformation and understanding the role of G-KF in the active tectonics of Nainital Himalaya using a dense geodetic dataset. The dataset includes Nine years (2013-2021) of campaign mode GPS measurements along with published GPS observations and InSAR line-of-site (LOS) velocity (ENVISAT and ALOS) in the study region. We use a velocity inversion model to combine the InSAR LOS and GPS velocity for the three-dimensional velocity field. We divide the whole Nainital Himalayan region into a mesh of triangular elements. The velocity signals in triangles are associated with the velocity of the triangles' vertices by an interpolation function. We use a Gamma smooth parameter to minimize the trade-off between the solution roughness and the weight the RMS misfit of the models. The inferred velocity field shows SW directed pattern with an average surface velocity of ~2 mm/yr. On the eastern side of the G-KF, we infer SW motion. However, on the western side, we observe westward motion. This different velocity pattern across the G-KF reveals some conspicuous surface deformation patterns, which may be related directly to the active tectonic movements along the study region. Based on our result we have also tried to create a deformation model, to understand and get a better knowledge of the tectonic deformation setting.

Preliminary Results of Earthquake Potential Estimation in Southern Sumatra, Indonesia Using GNSS Observations

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[2] Department of Geomatics Engineering, Institut Teknologi Sumatera, Indonesia

[3] Department of Earth and Planetary Sciences, School of Science, Nagoya University, Japan

[4] Department of Geodesy and Geomatics Engineering, Institut Teknologi Bandung, Indonesia

[5] Department of Earth Sciences, National Cheng Kung University, Taiwan

Thirteen continuous GNSS sites were built by the Geospatial Information Agency of Indonesia (BIG) in 2018 to reinforce the earthquake potential estimate in southern Sumatra, Indonesia, where is consisted of oblique Sumatra subduction zone and Sumatran strike-slip Fault Zone (SFZ). The occurrence of the 2007 Mw 8.5 Bengkulu earthquake in the past 20 years indicates the importance of earthquake potential evaluation in southern Sumatra. The GNSS data from those 13 new sites, as well as the other 11 continuous and 16 campaign-mode GNSS sites from 2017 to 2021 were therefore used to re-estimate the earthquake potential in this area. The GNSS data were processed by Bernese 5.2 software to obtain the daily coordinate solutions under the ITRF2014. Thirty horizontal velocities and seventeen vertical velocities were calculated by coordinate time series analysis. To eliminate the effect of postseismic deformation of the 2007 Mw 8.5 Bengkulu earthquake, the 2004 Mw 9.2 Sumatra-Andaman earthquake, the 2005 Mw 8.6 Nias earthquake, and the 2010 Mw 7.8 Mentawai earthquake from surface velocities, the postseismic deformations of those earthquakes were preliminarily inferred by forward modeling with viscosity of 2.5 x 1018 Pa s, and the effect is up to 2 mm/year. The baseline inversion model was further adopted to estimate slip deficit rate on four segments of the SFZ and 6 segments of curving interface. These faults accumulate energy of 1.57 × 1024 N m, equivalent to Mw 7.43. The energy is highly cumulated in the south of Enggano Island. The preliminary result shows that more than 99% energy cumulates on the interface. The more precise SFZ parameters and postseismic deformation model would increase the reliability of earthquake potential estimation in southern Sumatra.

Keyword: Crustal Deformation, Energy cumulation, GNSS velocity, Slip deficit rate, Sumatra

Session IV

Sub-surface Structure Mapping

Towards an Automated Workflow for the Creation of Complex 3D Fault Models

A. Howell[1,2], T. McLennan[3], C. Penney[1], A. Nicol[1], H. Seebeck[2], and B. Fry[2]

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[2] GNS Science, Lower Hutt, Aotearoa New Zealand

[3] Seequent Ltd, Christchurch, Aotearoa New Zealand

Fault geometry and the connectivity between faults at depth are both important controls on earthquake behaviour, so modelling these parameters accurately is essential to models of the earthquake cycle. However, the effects of uncertainties in fault geometry and connectivity are often not fully explored, partly because using current techniques building a fault model is difficult and time consuming. For example, the current 3D NZ Community Fault Model — which results from several hundred hours of work — represents only one of many hypothetical fault models that would be consistent with available constraints.

We present a preliminary automated workflow for the creation of 3D models of faults in Aotearoa New Zealand and worldwide, using python and the mesh-cutting capabilities of Leapfrog Software. This workflow creates a 3D fault model from: (1) GIS fault traces; (2) dip estimates; and (3) a text file containing information on which faults are thought to terminate against each other. Our approach is faster, more internally consistent and much less labour-intensive than previous (mainly manual) methods of fault model creation; it will allow a thorough exploration of the sensitivity of models to fault geometry and will therefore be of use in several diverse areas of earthquake science.

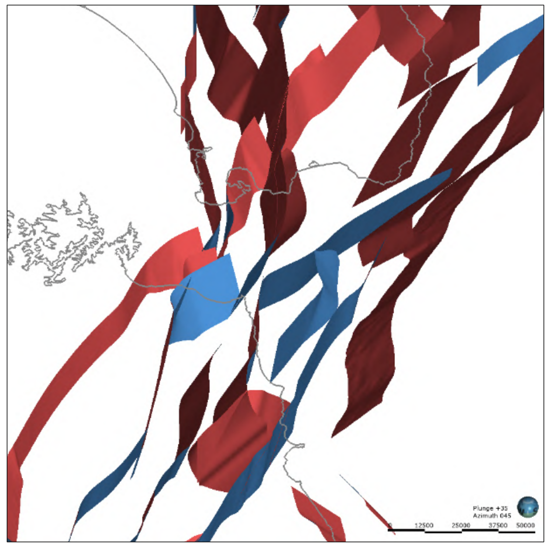

Figure 1. 3D model of faults in central Aotearoa-NZ created using our new method.

Session V

Ground Motion Prediction

Investigation of Shallow S-wave Velocity Structure and Site Response Parameters in Taiwan by Using High-density Microtremor Measurements

Chun-Te Chen[1], Chun-Hsiang Kuo[2,3,4], Che-Min Lin[4], Jyun-Yan Huang[4], and Kuo-Liang Wen[2]

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We published a paper describing shallow S-wave velocity structures throughout plains and foothills in Taiwan recently. We use the same topic as the title in the presentation in this workshop, and the same abstract was introduced in the following paragraph.

Site effect is considered a critical component affecting ground motions, and the shallow velocity structure is a primary factor for determining the site effect. The shallow velocity structure should be carefully evaluated to mitigate earthquake hazards. Thus, we use microtremor array measurements as well as the inversion of microtremor horizontal-to-vertical spectral ratios (MHVSRs) to investigate shallow S-wave velocity (Vs) profiles in Taiwan, which is one of the most seismically active areas of the world. On the basis of the diffuse field assumption, Vs profiles can be efficiently inverted. To reduce the non-uniqueness of MHVSR inversion, Vs profiles obtained using microtremor array measurements and from an engineering geological database were adopted as model constraints. Finally, this study included 3587 inverted MHVSR Vs profiles and 65 inverted Vs profiles from microtremor arrays. The results were used to create a detailed updated Vs30 map of Taiwan and to map the depth contours of Z1.0; thus, the relationship between Vs30 and Z1.0 was determined. We proposed a new parameter, HR, as a proxy for Vs30, that is defined as a ratio of the average MHVSR across high- and low-frequency bands. This parameter was correlated to the predominant frequency without subjective selection. Moreover, we constructed a pseudo- three-dimensional shallow Vs model of Taiwan, which describes main shallow structural features and provides complete details for plain areas.

Non-Ergodic Ground-Motion Model for Taiwan Subduction Earthquakes Based on 3-D Simulations

Chih-Hsuan Sung[1], Ming-Che Hsieh[2] and Norman Abrahamson[3]

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[3] Department of Civil & Environmental Engineering, UC Berkeley, CA, U.S.A

As sets of 3D simulations become more widely available, it is good opportunity to incorporate the information from the 3D simulations into ground motion model (GMM) used in seismic hazard calculations. Non-ergodic effects on the ground motions have been seen in the suite of numerical simulations of ground motions from megathrust earthquakes, such as the western US region, Seattle and Wasatch Front, Utah. In this study, we generated the suite of numerical simulations of ground motions from megathrust earthquakes on the Ryukyu subduction zone through a 3-D structure and chose a small site region in the middle Hualien that nears this subduction zone. Chao et al. (2020) (CCHL20) subduction zone GMM is ergodic, so we follow the process of Sung and Abrahamson (2022) to build the non-ergodic GMM based on the 3-D simulation results. First, the basin term of the CCHL20 GMM is modified to be consistent with the basin scaling from the 3-D simulations. Then, the spatial distribution of the non-ergodic terms is estimated using the varying coefficient model for the region covered by the simulations. In this case, we can see the strong radiation/directivity effects from 3-D simulation are captured through non-ergodic terms.

Summary of the SMK NGA-Sub Ground-motion Model for Subduction Earthquakes

Hongjun Si[1], Saburoh Midorikawa[2], Tadahiro Kishida[3]

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[2] Tokyo Institute of Technology, Tokyo, Japan

[3] Khalifa University of Science and Technology, Abu Dhabi, UAE

This presentation summarizes a ground motion model developed by Si, Midorikawa and Kishida for 5%-damped pseudo-spectral acceleration based on database of subduction earthquakes in Japan (SMK model) as a part of the GMMs developed for the Next Generation Attenuation (NGA) Subduction (NGA-Sub) project, a major research program to develop a database and ground motion models (GMMs) for subduction regions. The SMK model is based on the extensive, comprehensive subduction database for Japan by the Pacific Earthquake Engineering Research Center. The model predicts the RotD50 horizontal components of peak ground acceleration, peak ground velocity, and 5%-damped elastic pseudo-spectral acceleration ordinates in the selected periods ranging from 0.01 s to 10 s. The model includes predictor variables considering tectonic setting (i.e., interplate and intraplate), the hypocentral depths, magnitude scaling, distance attenuation, shallow soil and the basin responses. The magnitude scaling of interplate earthquakes is well constrained in Japan for different periods because the database includes the well-recorded large-magnitude events (i.e., the 2003 Tokachi-Oki and 2011 Tohoku earthquakes). The developed ground motion prediction equation covers the subduction earthquakes that occurred in Japan for moment magnitudes ranging from 5.5 to 9.1 with closest distances to the fault of less than 300 km.

References

Si H., Midorikawa S., Kishida T. (2022). “Development of NGA-Sub ground-motion prediction equation of 5%-damped pseudo-spectral acceleration based on database of subduction earthquakes in Japan”, Earthquake Spectra. May 2022. doi:10.1177/87552930221090326.

Comparison of Ground-Motion Models Based on the Strong Motion Database in Japan

Asako Iwaki[1], Nobuyuki Morikawa[1], Hiroyuki Fujiwara[1], Tomohisa Okazaki[2], Hisahiko Kubo[1], Hongjun Si[3], Atsuko Oana[4], Toru Ishii[4], Yusuke Tomozawa[5], Tomoki Hikita[5]

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In Japan, a huge amount of strong motion observation data has been collected by many institutions and companies, including more than 800,000 records by K-NET and KiK-net of NIED. We have been working on construction of a unified and expanded strong-motion database, aiming to contribute to improvement of the current PSHA in Japan through effective utilization of the observed records, including data-driven ground-motion prediction models (GMMs).

We have currently constructed a prototype of the unified strong motion database from all K-NET and KiK-net strong-motion records. The database consists of three files: seismic source, site, and strong-motion files. The seismic source file contains the earthquake information such as origin times and hypocenter locations by JMA, the moment tensor solutions by F-net, etc. The site file contains the information of the observation sites as well as the parameters for site characteristics such as VS30. The strong-motion file contains the indices such as PGA, PGV, acceleration response spectra, etc.

Several GMMs have been constructed using the database in common but via different approaches. In this study, we compare the characteristics of the six GMMs constructed by the coauthors. Among the six GMMs, three models are formulated by regression analyses, one model is derived by a non-parametric machine-learning approach, and two models are constructed by the combination of regression analyses and machine-learning approaches. In general, GMMs developed under ergodic assumption have large aleatory variability. By utilizing the adequate amount of observation records, it is important to model the regionally-specific ground motion characteristics as much as possible and relax the ergodic assumption. The six models used in this study adopt various approaches to model the site-specific terms to reduce the aleatory variability related to site effects. We compare the ground-motion prediction results from the GMMs at specific sites for different types of earthquakes under several conditions and examine the differences caused by the different modeling approaches.

Session VI

Earthquake Scenario Simulation (Part 1)

High-frequency Ground-shaking Simulations for Alpine Fault Earthquake Scenarios

Caroline Holden[1,2], J. Townend[2], C. J. Chamberlain[2], E. Warren-Smith[3], I. C. Juarez-Garfias[2], and O. Pita-Sllim [2]

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As part of the Southern Alps Long Skinny Array (SALSA) project, ~35+ seismometers have been deployed with 10–12 km spacing along a 450 km-long section of the Alpine Fault. SALSA is focused on determining the ground motions likely to be produced by a future Alpine Fault earthquake. This project is addressing three principal objectives: 1. Determine the Alpine Fault's subsurface geometry, present-day slip rates, and spatial variations in how tectonic stresses are currently accumulating on the fault; 2. Estimate the ground shaking that would be recorded at seismometers throughout central and southern New Zealand by localised slip at different points on the Alpine Fault; focusing on the synthesis of long-period Green's functions representing accurate path effects between sources distributed along the fault and population centers throughout the South Island. and 3. Calculate the ground shaking hazard from geologically-informed earthquake rupture scenarios. To achieve objective 3, the synthesis of high-frequency ground motion still needs to be addressed, however, and this will rely on better characterization of stress drops (Objective1) and attenuation models. Along with attenuation, stress drop affects synthetic spectra markedly. In this presentation we will address the influence of stress drop variation and of the attenuation function on high-frequency ground-shaking for Alpine Fault earthquakes.

Scenario-based Ground Motion Simulation on Practical Application in Seismic Mitigation for Hsincheng Fault in Taiwan

Yin-Tung Yen[1], Chun-Te Chen[1], Ming-Che Hsieh[2], Kuo-Fong Ma[2,3,4], Chung-Han Chan[2,4]

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[2] Earthquake-Disaster & Risk Evaluation and Management Center, National Central University, Taiwan

[3] Institute of Earth Sciences, Academia Sinica, Taiwan

[4] Department of Earth Sciences, National Central University, Taiwan

Earthquake mitigation is a continuous mission for a country with high seismic activity, like Taiwan. A destructive earthquake (ML7.1) attacked the southern Hsinchu and northern Taichung area on April 21, 1935. The mainshock was associated with two faults, the Shihtan fault in Hsinchu County and the Tuntzuchiao fault in Taichung City. This event resulted in severe damage and serious injuries. Due to urbanization, rapid economic growth (ex. science park), and aging buildings and infrastructures, the result of a future significant earthquake could be more devastating. Thus, it is crucial to mitigate the seismic impact by proposing catastrophic scenarios and considering earthquakes from nearby potential active faults or seismogenic structures. Such scenario cases could contribute to policy-making, drill preparation, and hazard preparation, enhancing society resilience and increasing hazard mitigation awareness for government, industry, and the public. Here, we reveal a potential scenario to apply to the practical application. We implemented a hybrid ground motion simulation with a characterized source model for the possible impact by induced strong ground motion from the Hsincheng fault. Moreover, we enhanced the extra consideration for curved fault geometry and avoided the shallow layer's near-fault effect. Finally, ground motion parameters extracted from simulated time history for the specific area will be helpful for the advanced seismic loss evaluation. The local government and industry risk prevention section can adopt the scenario as a drama for seismic preparedness and drill.

Keywords: earthquake mitigation, scenario ground motion simulation, characteristic source model, seismic preparedness

Quantitative Assessing the Variability of Earthquake-source Models to Ground Motion Prediction: A Case Study in the Ryukyu Subduction Zone

Ming-Che Hsieh[1], Yung-Ching Yang[2], Chih-Hsuan Sung[3]

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[2] Department of Earth Sciences, National Central University, Taoyuan, Taiwan

[3] Department of Civil & Environmental Engineering, UC Berkeley, CA, U.S.A

Historically, an M8 earthquake took place offshore east Taiwan in 1920. Studies on this earthquake indicate that the event might be related to the existence of the Ryukyu subduction zone. To estimate the possible ground motions in eastern Taiwan if earthquakes with similar magnitudes happen again, we assume an M8 scenario earthquake in the Ryukyu subduction zone. In order to capture the possible ground motions in our target region from the M8 scenario, a series of characteristic source models (CSMs) is generated according to the procedure of Recipe. Kinematic fault-rupture parameters are modeled, including rupture directivity, rupture speed, and asperity distribution. Therefore, a 3-D traction-image finite-difference method (FDM) is utilized to perform full-waveform ground motion simulations to test the variability of ground motions from the given CSMs. Tomographic velocity models and topographic relief are accounted for in these simulations. Each simulation costs about 14 hours, using 96 CPU cores to simulate 150-s wave propagation in the source-to-station region. A total of 24,755 fictitious stations with an inter-station spacing of 500 m are deployed to output 3-component synthetic waveforms. We adopt the RotD50 approach to calculate spectral acceleration and pick 3- and 5-second PSAs for ground motion model (GMM) analysis. The comparisons show that the simulations could be a good indicator of long-period ground motions and be further applied to adjust available GMMs and even seismic hazard assessment.

Keywords: Ryukyu subduction zone, characteristic source model, ground motion simulation, ground motion model

Session VIII

Seismic Risk Analysis

Extracting Building Response from the Low-cost QSIS Seismic Network (QSN) for Structure Integrity Monitoring

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To monitor the structural integrity, we have extracted the building response, shaking intensity, and associated resonance parameters from the seismic records by the newly developed QSIS (Quake Structure Integrity Sensor) Seismic Network (QSN). The development of QSN aims to support the community with an affordable and reliable building health monitoring system, which is composed of three primary components of low-cost and high-sensitivity sensor devices, data acquisition system and web data services. After shaker testing with standard seismometer, the collected acceleration records has been proven to be reliable with a root-mean-square noise level of 0.15 gal. Both the dominant resonance frequencies and the building response extracted from QSN by using the seismic interferometry can reveal the seismic wavefield in the building, which can be used to characterize the shaking behavior of the building. With the design of QSN, the building monitoring for seismic risk assessment and the rapid array mobilization for aftershocks become easier for researchers.

Session VI

Earthquake Scenario Simulation (Part 2)

Long-duration Ground Motion Simulation Using a Smoothing Scheme with a Diffusionized Wave Equation

Takahiro Maeda[1], Asako Iwaki[1], Shin Aoi[1], Hiromitsu Nakamura[1], and Hiroyuki Fujiwara[1]

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We have been performing long-period ground motion simulation by the finite difference (FD) method for great interplate earthquakes such as the Nankai Trough earthquake. However, it is sometimes difficult to calculate long-duration ground motion due to the instability in which the amplitude increases exponentially as the calculation time step increases. Although we have realized a long-duration ground motion calculation by smoothing the velocity structure model, we could not completely suppress the instability. Therefore, a Smoothing scheme with a Diffusionized Wave equation (SDWave) proposed by Imai et al. (2018) was introduced to the FD calculation of the ground motion simulator (GMS) developed by NIED to suppress the instability. The SDWave applies the analogy of the convection-diffusion equation to solve the modified wave equation with diffusion effects, and can selectively attenuate short-period components. Therefore, by appropriately setting the coefficient to be multiplied by the diffusion term, it is expected to eliminate only the influence of instability in the short period band rather than the period band that is effective for ground motion simulation.

In this study, we performed ground motion simulations with different velocity structure models, source models, and coefficients of the diffusion term. We investigated the effect of the coefficients on the wave field. First, a study using a simple calculation model (half-space medium & point source) was conducted. When the Fourier spectral ratios of multiple calculation results with different smoothing scheme coefficients and calculation result without the smoothing schemes are taken, the spectral ratio can be approximated by a Gaussian function with a coefficient proportional to the smoothing scheme coefficients. Next, a study using a realistic calculation model (3D velocity structure & finite source) was conducted. By properly setting the coefficients, instability was suppressed and long-duration ground motion could be calculated. On the other hand, it was found that the degree of attenuation of the short-period component is not spatially uniform.

It is an issue to study the setting policy of the coefficient of the wavefield smoothing scheme in a realistic calculation model and to improve the calculation method such as changing the coefficient temporally and spatially.

Acknowledgments: This study is part of ' Research Project for Disaster Prevention on the great Earthquakes along the Nankai Trough' funded by Ministry of Education, Culture, Sports, Science and Technology, Japan.

Rapid Characterisation of Earthquakes & Tsunami (R-CET Programme) – The Local Earthquake Challenge

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The R-CET Endeavour programme aims to advance and test modern methods to rapidly characterise earthquakes and tsunami, providing critical early information for response. Here, we present an overview of the Local Earthquake Group progress.

Rapid characterisation of local earthquakes is necessary to underpin immediate forecasts of an earthquake's likely impacts, e.g. tsunami, shaking, loss/damage, ground deformation, landslides, liquefaction and aftershock distribution/likelihood. Over the last decade of large earthquakes to impact New Zealand, robust models of an earthquake and its shaking have typically taken days to weeks to develop, with the initial response relying on a 'point source' model. The increasing availability and density of real-time seismic and geodetic (GNSS) data from the GeoNet network opens new possibilities to apply modern characterisation algorithms in near real-time.

We are actively exploring a suite of real-time earthquake tools including (i) FinDer for fault orientation, length and earthquake centroid (ii) w-phase for robust magnitude (Mww) and CMT, (iii) backprojection to map energy release, (iv) template matching for rapid aftershock characterisation and (v) GNSS and G-FAST algorithms for rapid geodetic displacement and finite fault and (vi) ShakingLayers (ShakeMap) that can be progressively updated with evolving source information during a response. The prototype tools are currently being used to create a suite of test products for major historical earthquake scenarios (e.g. Kaikōura and Dusky Sound earthquakes). This helps us build a timeline around what information could be available and when for first responders during the next big earthquake. It also allows us to test how we might best integrate complementary tools to build an improved common picture of an earthquake and its impacts. In the future we also intend to extend the scenarios to include large earthquake ruptures from the synthetic catalogue developed under the Resilience Science Challenge.

Tuesday, November 1

9:00	**Session VII: PSHA and Applications (Part 1)** **Chairs: Ruey-Juin Rau, Takashi Azuma**	
	Presenter	Presentation Title
9:00-9:15	Chung-Han Chan (National Central University, Taiwan)	Impacts of Clustering Events on a Probabilistic Seismic Hazard Assessment: A Case Study for Taiwan
9:15-9:30 (Virtual)	Nobuyuki Morikawa (National Research Institute for Disaster Resilience, Japan)	Update of Seismic Activity Model in Ryukyu Islands for Seismic Hazard Assessment in Japan
9:30-9:45 (Virtual)	Matt Gerstenberger (GNS Science, New Zealand)	The 2022 Aotearoa New Zealand National Seismic Hazard Model
9:45-10:00	Yi-Wen Mika Liao (GNS Science, New Zealand)	The Role of Frictional Heterogeneities in the Earthquake Cycle
10:00-10:20	**Discussion**	
10:20-10:40	**Coffee Break**	
10:40	**Session VII: PSHA and Applications (Part 2)** **Chairs: Ruey-Juin Rau, Takashi Azuma**	
	Presenter	Presentation Title
10:40-10:55 (Virtual)	Chris DiCaprio (GNS Science, New Zealand)	Computation and Data Management for Large Seismic Hazard Models: Application to the New Zealand National Seismic Hazard Model
10:55-11:10 (Virtual)	Kiran Kumar Thingbaijam (GNS Science, New Zealand)	The Workflow for the Distributed Seismicity and Slab Source Models in the New Zealand National Seismic Hazard Model 2022
11:10-11:25 (Virtual)	Sanjay Bora (GNS Science, New Zealand)	Candidate Ground-Motion Models (GMMs) and Associated Hazard Sensitivities for New Zealand National Seismic Hazard Model (NSHM-2022)
11:25-11:40 (Virtual)	Bill Fry (GNS Science, New Zealand)	Physics to Resilience: Next Generation Earthquake and Tsunami Response
11:40-12:00	**Discussion**	
12:00-13:30	**Lunch**	

13:30	**Session II: Active Faults and Paleoseismology (Part 1)** **Chairs: Chung-Han Chan, Caroline Holden**	
	Presenter	Presentation Title
13:30-13:45	Takashi Azuma (Geological Survey of Japan, AIST, Japan)	Active Fault Survey on "X-rank" Faults in Japan
13:45-14:00	Andy Nicol (University of Canterbury, New Zealand)	Incorporating Multi-fault Ruptures into the 2022 New Zealand Seismic Hazard Model
14:00-14:15	Jade Humphrey (University of Canterbury, New Zealand)	Implications of Paleoearthquake Timings and Synthetic Earthquake Catalogues for Fault Interactions in Central NZ
14:15-14:30	Cheng-Hung Chen (National Taiwan University, Taiwan)	Constructing the Offshore Seismogenic Structure Source Database by Taiwan Earthquake Model Project
14:30-14:50	**Coffee Break**	
14:50	**Session II: Active Faults and Paleoseismology (Part 2)** **Chairs: Chung-Han Chan, Caroline Holden**	
	Presenter	Presentation Title
14:50-15:05	Hung-Yu Wu (National Cheng Kung University, Taiwan)	Earthquake Recurrence Interval and Stress Status in Milun Fault, Hualien, Taiwan
15:05	**Session I: Records and Analysis of Recent Large Earthquakes** **Chairs: Chung-Han Chan, Caroline Holden**	
	Presenter	Presentation Title
15:05-15:20 (Virtual)	Chris Rollins (GNS Science, New Zealand)	The Rates of Moderate and Large Earthquakes in the New Zealand Region, and Their Uncertainties
15:20-16:30	**Discussion and Poster**	
18:00-20:00	**Dinner (Buffet room)**	

Session VII

PSHA and Applications (Part 1)

Impacts of Clustering Events on a Probabilistic Seismic Hazard Assessment: A Case Study for Taiwan

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In this study we validate the impact of earthquake declustering approaches and blind faults on the application of probabilistic seismic hazard assessment (PSHA) for Taiwan. According to a standard procedure of PSHA, clustered events, which are dependent on each other (i.e., foreshocks and aftershocks), should be removed from an earthquake catalog using a declustering approach. However, such clustered events which could be helpful to identify blind fault structure that potentially impact seismic hazard are often neglected. We first applied four declustering approaches, including the Epidemic-Type Aftershock Sequence (ETAS), the Nearest Neighbor Approach (NNA), the Double-link declustering method (DL), and the Gardner and Knopoff declustering method (GK), to the catalog from 1990 to 2020 from the Central Weather Bureau. Based on the declustered catalogs and the derived Gutenberg-Richter relations, we then proposed seismogenic models for PSHA. Among which, while the DL-declustered catalog remains the most events and results in relatively higher hazard level in central and southwestern Taiwan, only the ETAS- and NNA-declustered catalogs pass the Poisson process test. We then identified fault geometries using the distribution of clustered seismicity from the NNA. Using a threshold of the planarity higher than 0.6, 41 fault planes were identified and most of them are blind faults without surface traces. Considering seismic activity on each newly identified fault, we obtained elevation of seismic hazard level near the faults with high seismic activities (i.e., large a-values) at shallow depths. Incorporating blind faults into PSHA could better reflect potential hazard to mitigate seismic loss due to devastating earthquakes on those unmapped blind faults, such as the 2016 Mw6.5 Meinong, Taiwan, earthquake.

Update of Seismic Activity Model in Ryukyu Islands for Seismic Hazard Assessment in Japan

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The Headquarters for Earthquake Research Promotion (HERP) of Japan published the “Long-term evaluation of seismic activities in the Hyuga-nada and along the Ryukyu Islands Trench (2nd edition)” on March, 2022. Based on this evaluation, we are now updating our seismic activity model from Kyushu to the Ryukyu Islands region for seismic hazard assessment in Japan.

A new geometry model of the top surface of the subducting Philippine Sea Plate based on recent reflection/refraction surveys and so on is presented in the long-term evaluation. We joined this geometry model with a model for the Nankai Trough region in the Hyuga-nada region. However, there is no model for the area west of 123°E.

A magnitude 8-class subduction-type earthquake in the Hyuga-nada was newly indicated in the long-term evaluation. While earthquakes in which the Nankai Trough region and the Hyuga-nada region are active simultaneously have already been modeled, magnitude 8-class earthquakes in the Hyuga-nada region alone have not been modeled. Therefore, we set up source fault models for both inter-plate and intra-slab earthquakes. However, such earthquakes are not known to have occurred in the past, and their frequency has not been evaluated. So, we have not been able to model the frequency of magnitude 8-class earthquakes in the Hyuga-nada yet.

Zoning for background earthquakes will be modified according to the long-term evaluation. This modification applies to subduction earthquakes on the Philippine Sea Plate as well as crustal earthquakes. The frequency of earthquakes in each zone is modeled assuming the Gutenberg-Richter’s relationship using the earthquake catalog from the Japan Meteorological Agency.

The maximum magnitude of inter-plate earthquakes in the Hyuga-nada is set at 8.4 based on the area of source region. The maximum magnitudes of inter-plate earthquakes in Ryukyu Islands and intra-slab earthquakes are assumed to be 8.5 and 8.0, respectively, the same as current model.

In addition, we have started modeling ocean-bottom active faults in the Ryukyu Islands region.

Anyway, our new seismic activity model for the Ryukyu Islands remains large uncertainties regarding the frequency and maximum magnitude 8-class earthquakes.

The 2022 Aotearoa New Zealand National Seismic Hazard Model

M. C. Gerstenberger[1], Sanjay Bora[1], Brendon Bradley[2], Chris DiCaprio[1], Anna Kaiser[1], Elena Manea[1], Andy Nicol[2], Mark Stirling[3], Kiran Thingbaijam[1], Russ Van Dissen[1] and the NSHM Team

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The 2022 Aotearoa New Zealand Seismic Hazard model is a significant revision in all model components. Changes to the seismicity rate model (SRM) include a focus on removing strict segmentation from ruptures on known faults. This allows for modelling of more realistic ruptures including uncertainty in both magnitude and length of possible ruptures. Additionally, more low-probability high-impact ruptures were included than were possible in the past. Specific low-seismicity region models were used that allow for the greater variability in occurrence rates that are observed in similar regions around the world. Finally, the SRM targets a 100-year forecast and models the variability in the occurrence rate that is greater than has been included in the past.

The Ground Motion Characterisation Model (GMCM) includes the use of multiple ground models (GMMs) for each tectonic type and includes internationally developed models (e.g., NGA). A new ground motion database has been compiled for assessment of the international models and for the development of two NZ backbone GMMs. The GMCM is a significant departure from past NSHMs and produces noticeably different ground shaking forecasts, both in median spectral values (and shape) and epistemic uncertainty. The large number of models used allow for the hazard results to include a large range of uncertainty in what the true hazard is.

Overall, the hazard forecast is increased in almost all parts of New Zealand compared to the 2010 model. On average the increase is about 50%, but this can vary significantly for any location or shaking frequency. Importantly, the revision estimates shaking for Vs30 rather than NZ Site Class, and this makes comparison to previous models challenging; there is no clear mapping between them. Finally, the range of increases are from roughly no change to more than doubling of the hazard.

The Role of Frictional Heterogeneities in the Earthquake Cycle

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The determination of earthquake source models for seismic hazard assessments can be difficult and highly uncertain. Information such as recurrence interval of earthquakes for a given magnitude, earthquake origin and probability of multiple-segment rupture is often poorly constrained, especially for large earthquakes (M>7.0). Physics-based earthquake simulators offer a means of assessing uncertainties of hazard-related input parameters. Importantly, they also provide a pathway for future generations of seismic hazard models in which ground motions are calculated by modelling the seismic wave field, including the effects of variability in the earthquake source process. Earthquake simulators such as RSQSim, an earthquake simulator generating earthquakes basing on rate-and-state friction law, generate long-term synthetic earthquake catalogs on a system of known faults. This may help reduce the uncertainties of the inputs of hazard assessment. In order to obtain realistic earthquake catalogs for hazard assessment with RSQSim we explore the effects of varying a priori input parameters. We test the effects of different initial stress models and rate and state dependence constants (a and b) for earthquake cycle simulations of the Hikurangi-Kermadec subduction zone. We compare our results with the magnitude frequency distribution of the observed earthquake catalog and empirical scaling laws from previous studies as a first-order test of the synthetic catalogs. The comparison between different initial stress models shows that using heterogeneous rather than uniform initial stress on the fault plane produces

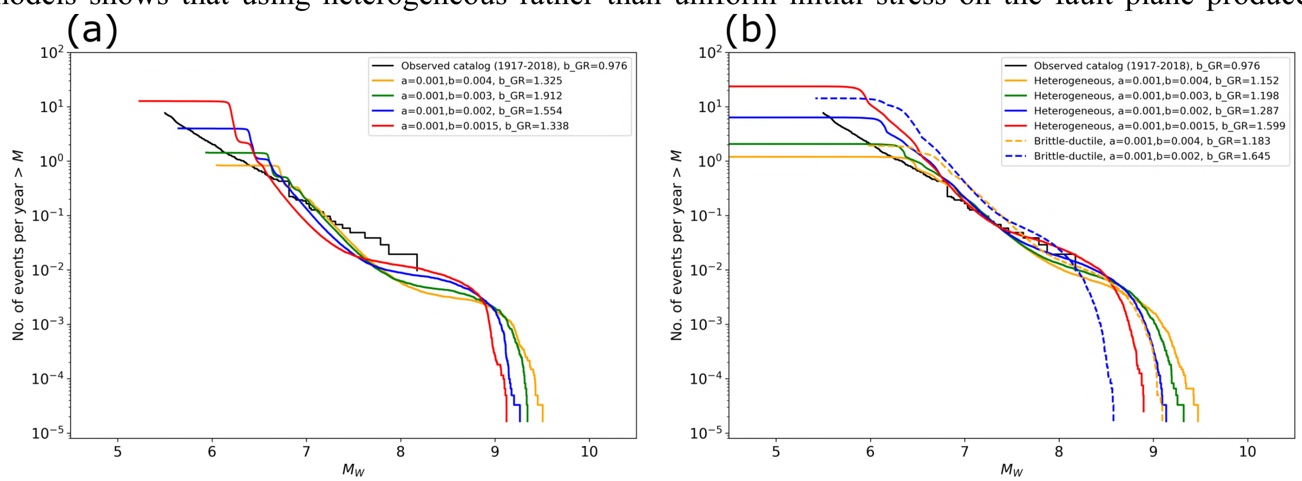

Figure 1. Magnitude-frequency distribution (MFD) of the models compared to the observed historical catalog. (a) MFDs for homogeneous stress models; (b) MFDs for heterogeneous and brittle-ductile stress models presented as solid and dashed lines, respectively. Black line is the MFD of observed catalogue. The state coefficients of 0.004, 0.003, 0.002 and 0.0015 are shown as orange, green, blue, and red curves.

synthetic earthquake catalogs that are less characteristic and more comparable to the historical catalog (Figure 1). The comparison of scaling of rupture area, co-seismic slip (Figure 2) and stress drop obtained simultaneously with the synthetic catalogs indicates that smaller b (with fixed a) could result in smaller co-seismic slips and stress drops and similar values to the empirical scaling laws. The results indicate the heterogeneity of other stress parameters could be applied to the RSQSim inputs as the next steps to improve the applicability of the synthetic earthquake catalogs to fundamental and applied seismic hazard problems.

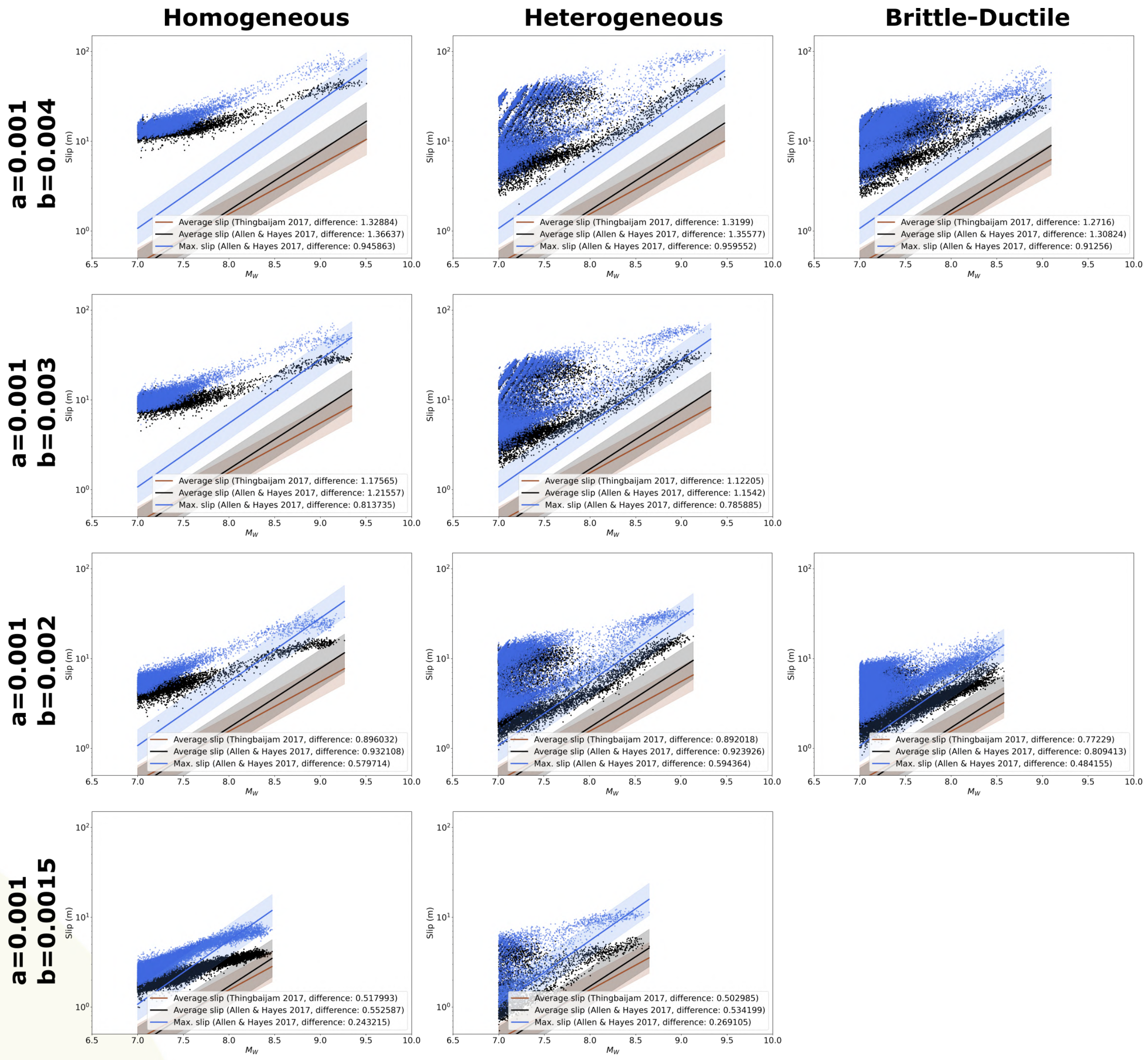

Figure 2. Scaling of maximum and average coseismic slip with earthquake magnitude. Columns from left to right are homogeneous, heterogeneous and brittle-ductile stress models respectively; rows from top to bottom are models with state coefficients of 0.004, 0.003, 0.002, and 0.0015 respectively. The maximum and average coseismic slip are presented as blue and black dots for earthquakes from the synthetic catalogues. Empirical scaling laws of maximum (blue lines) and average (black and brown lines) slips (Allen & Hayes, 2017; Thingbaijam et al., 2017) are also plotted as references for understanding how reasonable the synthetic slips are. The uncertainty of the empirical of the empirical scaling laws is represented by light blue (max slip), grey (average slip Allen and Hayes, 2017) and light brown (average slip Thingbaijam 2017).

Session VII: PSHA and Applications (Part 2)

Computation and Data Management for Large Seismic Hazard Models: Application to the New Zealand National Seismic Hazard Model

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The 2022 New Zealand National Seismic Hazard Model (NZ NSHM) represents a massive revision of the NZ NSHM across both seismicity rate model (SRM) and ground-motion characterization model (GMCM) components. A primary goal of this model is to capture a large range of epistemic uncertainty in both source and ground motion. As a result, the final SRM logic tree comprises 324 branches and the (GMCM) logic tree comprises 3024 branches. The final logic tree contains nearly 1 million branches, posing a significant computational challenge.

Our approach to the problem is to break the logic tree into several parts, dividing it by source components (active shallow crust, Hikurangi-Kermadec subduction interface, Puysegur subduction interface, and subduction slab) which are considered independent. Hazard curves can be practically calculated for individual source components. Weighted mean and quantile hazard curves are then calculated from the constituent parts in a post-processing phase. This approach has additional advantages as it allows us to easily reconstruct all hazard curve realizations for the purposes of exploring individual components of the hazard model, performing sensitivity tests, calculating new aggregate statistics, and performing disaggregations over the full logic tree.

The large number of source components of the NZ NSHM also poses a data management challenge. We've developed tools to make access to model components and metadata easy and ubiquitous. This facilitates sharing of results among the scientific team, tracking components of the large SRM logic tree, and providing model components to the public.

Session VII

PSHA and Applications (Part 2)

Candidate Ground-Motion Models (GMMs) and Associated Hazard Sensitivities for New Zealand National Seismic Hazard Model (NSHM-2022)

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The 2022 revision of the national seismic hazard model (NSHM) for New Zealand involves a massive update in terms of seismicity rate models (SRMs) and the ground-motion characterization modeling (GMCM). In that context, to capture epistemic uncertainty GMCM adopts a hybrid approach, that involves using a multimodel approach along with backbone ground-motion modeling framework. For active shallow crustal sources seven GMMs were considered that include four global, one New Zealand specific GMM and two New Zealand specific backbone GMMs developed within the purview of NSHM-2022. Similarly, the candidate models for subduction (interface/intraslab) sources include three recently developed global GMMs (NGA-Sub) and one New Zealand specific backbone model.

The candidate GMMs were assessed by performing comparisons of median ground-motions and aleatory uncertainty in addition to the data driven evaluations that were carried-out using the global data-sets as well as a recently compiled strong motion database for New Zealand. Moreover, for subduction GMMs, corrections were also made in the median models for backarc distance scaling and in the aleatory sigma model for soil non-linear effects. We demonstrate the impact of updated GMCM on the hazard calculations: 1) by showing comparisons with respect to 2010-GMCM and 2) relative sensitivity of different GMMs and parameter choices corresponding to different source types. Final weights on different models were decided after an expert elicitation workshop.

Physics to Resilience: Next Generation Earthquake and Tsunami Response

Bill Fry[1], Andy Nicol[2], Anna Kaiser[1], Mika Liao[2], William Power[1], Nick Horspool[1], Andy Howell[1,2], Chris Massey[1], Bruce Shaw[3], Laura Hughes[4], Camilla Penney[2]

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Public funding of science is increasingly leveraged to provide direct benefit to society. In this talk, we will present one such case. We will give an update of the Resilience to Nature's Challenges (RNC) national science challenge Earthquake and Tsunami Programme and show how this model is being used to address critical DRR initiatives. This programme has implemented NZ's first national-scale earthquake simulator. Our current working national earthquake models represent hundreds of thousands of years of possible earthquakes in New Zealand. Earthquakes in this synthetic seismicity model exhibit remarkable complexity, beyond that usually considered in scenario-based event response planning.

Ongoing efforts are aimed at evaluating the usefulness of these earthquake models for application to some of NZ's biggest earthquake challenges. The scope of our current applications includes, but is not limited to exploring 1) next-generation seismic and tsunami hazard modelling and 2) providing input scenarios to improve large local and regional earthquake and tsunami response tools.

We will show how the RNC synthetic seismicity catalogue is being used to test response tools and early warning procedures through the exploration of primary, secondary and tertiary perils resulting from big earthquakes. As an example, we will show testing and application of regional tsunami early warning algorithms under the Rapid Characterisation of Earthquakes and Tsunamis (R-CET) MBIE Endeavour programme. We will also show how the catalogues can be utilized to "stress test" our fundamental response structures by providing comprehensive event scenarios that explore a greater range of stochastic variation of the hazard than traditional response testing methods. These scenarios stretch to include strong ground motion, landsliding and tsunami hazards and are noteworthy due to their complex nature, involving primary and triggered multi-fault ruptures.

Session II

Active Faults and Paleoseismology (Part 1)

Active Fault Survey on "X-rank" Faults in Japan

Takashi AZUMA

Geological Survey of Japan, AIST, Japan

The Headquarters of Earthquake Research Promotion of Japan (HERP) conducts a project on "Surveys for the progress and optimization of active fault evaluation" since 2019. Main purpose of this project is to obtain information of the slip-rata of "X-rank" faults in Japan. HERP uses a classification of major active fault zone with ranks of S-, A- and X. S-rank is a group of active fault zone with very high probability for 30 years (more than 10 %) whereas A-rank is those with > 1%. Active fault zones of X-rank luck fault parameters, such as slip-rate, age of faulting events, and could not calculate probabilities.

We, Geological Survey of Japan, started to survey of X-rank faults, using new survey methods.

In the first project, we chose 15 fault zone, including 2 normal faults, 5 reverse faults and 8 strike-slip faults during 2019-2021. In this presentation I would like to show examples of results of a reverse fault (Shibetsu) and 4 strike-slip faults (Itsukaichi, Tsutsuga, Jifuku and Ooharako). For the Shibetsu fault zone, UAV LiDAR survey was conducted to obtain a detailed topographic data. Amounts of vertical deformation were estimated by using such a topographic data. Age of fluvial terraces were decided based on tephrochronology and 14C dating. Vertical slip-rate of the Shibetsu fault zone is calculated as ca. 0.3 m/ky. For the estimation of slip-rate of strike-slip faults, relationship between stream offset and length of upstream. Slip-rate of the Tsutsuga fault was reported by a recent study and it allows to estimate a value of coefficient, which indicate relationship of slip-rate and offset ratio (offset/upstream length) in this area. This study will lead to new methods with the cosmogenic dating to estimate erosion rate of the affected area.

Session II

Active Faults and Paleoseismology (Part 1)

Implications of Paleoearthquake Timings and Synthetic Earthquake Catalogues for Fault Interactions in Central NZ

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Forecasting the probability and magnitude of future large-magnitude earthquakes is typically dependent on information collected from paleoearthquakes. These paleo-records are often incomplete and the timing of earthquakes imprecisely known, which impacts our ability to estimate their fault slip, recurrence intervals and magnitudes. In particular, paleoearthquakes are often not sufficiently detailed to provide unambiguous constraints on the frequency and geometries of the multi-fault ruptures that have been so widely observed historically in New Zealand.

To improve understanding of the factors controlling multi-fault earthquakes, we compare the timing of earthquakes between active faults in central New Zealand. We use a compilation of more than 150 existing radiocarbon dates recalibrated using OxCal V4.4 to determine the timing of earthquakes. Bayesian statistics are applied to test and quantify the probability of earthquake synchroneity between different faults and segments of the same fault.

The refined analysis provides improvements for the timing of paleoearthquakes for the faults studied. These new ages indicate that in some cases, the timings of surface-rupturing earthquakes vary between faults. In other cases, inferred paleoearthquakes on different faults are approximately the same age, suggesting interactions across fault systems, either resulting in earthquake triggering or multi-fault ruptures.

We take these revised ages from the paleoearthquake record and compare them to the outputs of synthetic RSQSim models produced in New Zealand. We consider the importance of magnitude of completeness for comparing synthetic catalogues and paleoseismic records. We discuss how the utility of simulators for understanding individual surface-rupturing earthquakes and seismic hazards can be further tested.

Constructing the Offshore Seismogenic Structure Source Database by Taiwan Earthquake Model Project

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Taiwan is a young active orogenic belt with many active seismic structures and frequent earthquake activities. Understanding seismogenic characteristics of structures in different areas before earthquake occurrence is a key to reducing the losses caused by earthquakes. Currently, the Taiwan Earthquake Model (TEM) project has published 45 on-land structures, and such information has been used by the government and many scholars for disaster preparations. However, despite reports of active structures and many historical earthquakes offshore Taiwan, there is still a lack of a comprehensive database of offshore seismogenic structures.

Determining the location and activity of offshore structures is a major challenge in earthquake hazard assessment. In this study, we attempt to integrate results from previous geological and geophysical studies to determine the possible locations and subsurface geometry of seismogenic structures. We also designed appropriate estimation methods to obtain earthquake parameters such as long-term slip rate, possible magnitude, and recurrence interval for structures located in different geological regions. For example, using offset features in seismic profiles and the inferred age based on the general tectonics of northern Taiwan, the long-term slip rate of normal faults off northeast Taiwan is estimated to be from 0.1 to 2 mm/yr, with recurrence intervals of 100 to 42000 years. At present, we have integrated and mapped 51 offshore seismogenic structures, of which 21 structures have parameters estimated. Due to the limitation of seismic data quality and topographic resolution, these structural parameters still have large uncertainties and need to be refined. We hope that once this database is fully established, it will facilitate better earthquake hazard calculations for Taiwan.

Keywords: Taiwan Earthquake Model (TEM), earthquake hazard, seismogenic structure, structure parameter.

Session II

Active Faults and Paleoseismology (Part 2)

Earthquake Recurrence Interval and Stress Status in Milun Fault, Hualien, Taiwan

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Taiwan Earthquake Model announced that the magnitude over 6 earthquakes occurred on Milun fault is determined to 67 percentage possibility in upcoming century. From the historical records, Milun fault were recorded two significant ruptures in 1952 and 2018. The recent slip brought out the scientific drilling project, MIDAS (Milun fault Drilling and All-inclusive Sensing). With the crust physical properties collected from MIDAS, the fine-tuned Rate and State Earthquake model can be generated to simulate the earthquake recurrence interval and the stress drop on the fault plane. Considering the tectonic stress level in eastern Taiwan, the 3 faults system, including the Longitudinal-Valley fault and Central-Range Structure, were set in RSQSIm model. After the 20,000 years simulation, the synthetic seismic catalogs is generated with the stress accumulation and the event-driven time snap slip. In this study, we use this simulator to produce the dynamic rupture model of Milun fault and determine its heterogeneous stress change in the rupture process.

Session I

Records and Analysis of Recent Large Earthquakes

The Rates of Moderate and Large Earthquakes in the New Zealand Region, and Their Uncertainties

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For use in the Seismicity Rate Model (SRM) component of the 2022 New Zealand National Seismic Hazard Model, we estimate the total magnitude-frequency distribution (MFD) of earthquakes in the greater New Zealand region and along the Hikurangi–Kermadec and Puysegur subduction zones. The former is a key input into multiple components of the SRM in the onshore and near-shore regions, while the latter is a key input into models of earthquake rupture rates on the subduction zones.

Recent work (Christophersen et al., 2022) has greatly improved and homogenized the earthquake magnitudes in the New Zealand earthquake catalogue for use in the NZ NSHM 2022. Other parameters in the catalogue remain of mixed quality, however, in particular earthquake depths. Therefore, we develop an augmented New Zealand earthquake catalogue in which we import higher-quality depths and depth uncertainties, focal mechanisms, and some locations and magnitudes from several relocated and global catalogues. Next, we use event depths, focal mechanisms, 3D models of the Hikurangi and Puysegur subduction interfaces, and relative plate motion directions to classify earthquakes as upper-plate, interface or intraslab.

Using this augmented catalogue and adapting an approach used previously in California, we estimate the MFD of earthquakes in the near-shore region incorporating data back to 1843, balanced with the better data in the more recent part of the instrumental catalogue. This method estimates both the mean earthquake rate and its uncertainty, and we supplement it with an alternative estimate of the rate uncertainty that is based on the rate variability in the catalogue over a range of shorter timespans. We estimate the MFDs on the Hikurangi–Kermadec and Puysegur subduction zones using a simplified version of the method used in the near-shore region, with more recent data. Finally, we describe a globally based method to estimate the potential earthquake rate uncertainty on the Hikurangi–Kermadec subduction zone.

Session I

Records and Analysis of Recent Large Earthquakes

Poster Presentations

Poster Code: P-01

Determining Co-seismic Spatio-Temporal Characteristics of the 2016, M_w 7.8, Kaikoura Earthquake through EOF Analysis

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The co-seismic deformation analysis is of great significance for the interpretation of associated spatio-temporal deformation pattern of large earthquake and preliminary understanding of fault geometry. In order to investigate the co-seismic deformation, several classical techniques, such as Elastic Dislocation Model (EDM) and Least-Squares Estimation (LSQ) have been previously used. These classical methods may provide inadequate results, probably due to (i) necessity of a-priori values (often subjective) of the hyperparameters in the geodetic inversion; (ii) inefficiency in analyzing complex time series which have inter-seismic, co-seismic, and post-seismic signals simultaneously, and (iii) elusive information in the presence of outliers, noise, influential values, and bad leverage points that somehow break down the method implementation. In view of this, the present work proposes a “self-organized data-adaptative” method, namely Empirical Orthogonal Function (EOF), in elucidating the co-seismic deformation field caused by the 2016, M_w 7.8, Kaikoura earthquake of New Zealand. The EOF method is capable of decomposing a coherent space time data into individual spatial patterns and associated time scales. The obtained EOF mode, as a pair of spatial pattern and time history, enhances the prominent deformation patterns, such as co-seismic signal, post-seismic signal and common mode error, simultaneously. In the present study, for EOF-based analysis, we incorporate the 30-min sampling continuous GPS data during the time span of 15 days straddling the Kaikoura earthquake. The emanated EOF results lead to the following observations: (i) the northern South Island propagates in the northeast direction with the amplitude of 200 mm in North and 150 mm in East; (ii) the north Canterbury domain is uplifted with 150 mm along the offshore boundary; (iii) the post-seismic relaxation resembles to the co-seismic pattern along with the SW-NE trend from the central South Island to the North Island, and (vi) the horizontal co-seismic strain pattern reveals a notable radial SW-NE stretching coupled with existing dominant strike-slip with reverse faulting. Moreover, the EOF results are superior to the conventional LSE method. In summary, the proposed EOF analysis not only sheds light on the leading co-seismic information from geodetic observations and but also provides further insights toward a better understanding of the tectonics of New Zealand.

Keywords: Co-seismic analysis, Empirical orthogonal function, Kaikoura earthquake

Poster Code: P-02

Multi-fault Rupture Database and Its Applications to Taiwan Earthquake Model (TEM)

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Multi-fault rupture earthquake is an event which involved near-simultaneous or cascading rupture on two or more faults in one single earthquake event, and results in a larger magnitude that exceeds the capable magnitude of any single seismogenic fault involved in the earthquake. Although the unexpected earthquake magnitude may have high impact on the seismic hazard assessment, the geological condition to promote multi-fault rupture in single earthquake is yet well-studied. Hence, we collect worldwide cases of multi-fault ruptures and aim to build up a database focusing on spatial relationships between cascading rupture faults and their physical characteristics (e.g., fault types, geometries).

Our preliminary observations show that strike-slip faulting events have more frequent occurrence of multi-fault rupture than dip-slip faulting events in the global database. In terms of the structural discontinuities that may arrest the coseismic ruptures, our data suggest the “5-km” surface fault separation may not act as the termini to stop all the strike-slip fault ruptures. Besides, in the cases of reverse faults, the coseismic ruptures could jump further than strike-slip faulting cases. This difference is likely resulted in the 3D geometries and distances between adjacent faults since reverse faults tend to have gentler geometries at depth, compared to strike-slip faults. In addition, the strike variation between two contributing faults also affects the multi-fault rupture scenario, our data shows that for strike-slip faulting cases and reverse faulting cases, if the strike variation between two faults is in the range of 40-80 degrees, multi-fault rupture would not happen on them. With the consideration which faults can appear separate at the surface, but are actually linked in depth, we plan to incorporate these findings into the 3D seismogenic structure model of Taiwan, to improve the assessment of possible multi-fault rupture scenario database in Taiwan Earthquake Model.

Keywords: Multi-fault ruptures, earthquake scenario, seismic hazard assessment, Taiwan Earthquake Model (TEM)

Poster Code: P-03

Constructing the Offshore Seismogenic Structure Source Database by Taiwan Earthquake Model Project

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Taiwan is a young active orogenic belt with many active seismic structures and frequent earthquake activities. Understanding seismogenic characteristics of structures in different areas before earthquake occurrence is a key to reducing the losses caused by earthquakes. Currently, the Taiwan Earthquake Model (TEM) project has published 45 on-land structures, and such information has been used by the government and many scholars for disaster preparations. However, despite reports of active structures and many historical earthquakes offshore Taiwan, there is still a lack of a comprehensive database of offshore seismogenic structures.

Determining the location and activity of offshore structures is a major challenge in earthquake hazard assessment. In this study, we attempt to integrate results from previous geological and geophysical studies to determine the possible locations and subsurface geometry of seismogenic structures. We also designed appropriate estimation methods to obtain earthquake parameters such as long-term slip rate, possible magnitude, and recurrence interval for structures located in different geological regions. For example, using offset features in seismic profiles and the inferred age based on the general tectonics of northern Taiwan, the long-term slip rate of normal faults off northeast Taiwan is estimated to be from 0.1 to 2 mm/yr, with recurrence intervals of 100 to 42000 years. At present, we have integrated and mapped 51 offshore seismogenic structures, of which 21 structures have parameters estimated. Due to the limitation of seismic data quality and topographic resolution, these structural parameters still have large uncertainties and need to be refined. We hope that once this database is fully established, it will facilitate better earthquake hazard calculations for Taiwan.

Keywords: Taiwan Earthquake Model (TEM), earthquake hazard, seismogenic structure, structure parameter.

Poster Code: P-04

Seismogenic Structure Identification and Modification Processes of the Taiwan Earthquake Model (TEM): Examples from the Changhua Fault and Chungchou Structure

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Seismogenic structure database is an important input for Probabilistic Seismic-hazard Analysis (PSHA) in the Taiwan Earthquake Model (TEM) project. In 2016, we published the first version of the seismogenic structure database, with 38 on-land seismogenic structures. In 2020, we reviewed and updated the database. 7 structures were added, and the details of structural locations were modified. In this study, we use the Changhua fault and the Chungchou structure as examples to illustrate the identification and modification processes of these structures.

The Changhua fault is a published and well-known active structure in Taiwan. In the 2016 version, we mapped this fault along the western edge of the Houli Tableland, and extends southward to the western edge of the Tatu and Pakua Tablelands. The fault then turns southeastward along the Chingshui River valley. This location is based on previous observations that a series of uplifted terraces are present along the the eastern side of the Chingshui River. Since the terrace surfaces were tilted eastward, they may be comparable to the east-tilted Pakua Tableland. Since the Touliu Hills on the western side of the Chingshui River is not tilted, we believed in our 2016 version that the Changhua fault should be located between the tilted terraces and the Touliu Hills. However, later some new investigations suggest that the Touliu Hills may be the crest of an anticline that is comparable to the Pakua anticline. Therefore, we have changed the location of the Changhua fault to the western side of the Touliu Hills, approximately at the same location as the Tongshuhu fault in the geologic map of Taiwan published by the Central Geological Survey.

The Chungchou structure is a seismogenic structure that only present in the TEM database. The 2016 version of this structure is mapped by connecting many of the previously identified geomorphic features, such as linear scarps that are located along the mountain front in southern Taiwan. The 2020 version, however, also used the surface deformation patterns of the 2016 M6.4 Meinong earthquake to modify the location of the southern part of the Chungchou structure. Based on the surface deformation patterns, the southern segment of the structure no longer follows the mountain front. However, since geomorphic feature along this segment is absent, future rectification of the structural location is likely needed.

Poster Code: P-05

Active Structural Characteristics in the Southern Western Foothills of Taiwan

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The densely populated plains of southwestern Taiwan face a high seismic risk, and understanding the active structural characteristics in this area is a priority in earthquake hazard assessment in Taiwan. Many previous studies have mapped a potentially seismogenic Chungchou structure along the western side of the Chungchou Tableland, but the location of the structure and its long-term uplift rate are still controversial. In this study, we first mapped all possible active structures in this area based on tectonic geomorphic features using a high-resolution Digital Elevation Model, and performed field investigations on the detailed topographic manifestation of these structures. These will be followed by detailed topographic surveys and trench excavations to obtain the long-term uplift rates of the structures. Our current results show that most of the tectonic geomorphic features are found along the western side of the Chungchou Tableland and the mountain front of the Foothills. Along the western Chungchou Tableland, a gentle flexural scarp facing westward is present, and its height ranges from 5-6 meters south of Rende to 1-2 meters both to the north and to the south. We interpret this scarp to represent an east-dipping reverse fault beneath the Chungchou Tableland. Along the foothill mountain front, there is a series of discontinuous structural scarps with heights of about 2 meters. These scarps appear to be discontinuous and truncated across the east-west striking dextral Hsinhua fault, and we interpret this to represent the influence of a flower structure of the Hsinhua fault system. There is a scarp facing eastward northwest of Guanmiao, and another facing westward in the southeast. During the 2016 Meinong earthquake, surface ruptures were observed on both structures. We will continue to conduct detailed topographic surveys and trench excavations to further characterize these structural features. Our new results show a clear difference in structural distributions from those published in the Taiwan Earthquake Model (TEM) database. Therefore, the seismogenic structure characteristics of the southern Western Foothills of Taiwan need to be further investigated and updated.

Poster Code: P-06

The Study on the Seismic Mechanism of the 2017 Zhushan Seismic Swarms

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Taiwan is located at the junction of the collision of the Eurasian plate and the Philippine Sea plate, and is located on the western foothills at the front end of the orogenic belt, where seismic activity is frequent. It is noted that most of the events are shallow earthquakes, and high potential seismic hazards must be considered. In this study, the seismogenic mechanism and subsurface structure of two swarm events（11 and 22）in the Zhushan area of Nantou in November 2017 were investigated with respect to their source depth and location distribution characteristics.

The results of the source distribution after repositioning by HypoDD indicate that both swarm events have a vertical distribution, with the central location concentrated in the same area, with a radius of about 2.5 km and depth distribution in the range of 10-20 km. The largest earthquakes have a depth of about 15 km. The frictional force of the best solution obtained in the calculation of the stress direction also tends to be lower compared to other earthquakes（where the low frictional force is considered to be a manifestation of high pore water pressure）. In addition, by relocating the seismic events through the 3D velocity model, this study allows us to image the active structures associated with these earthquake swarms. We also analyze the seismogenic mechanisms of these swarms and perform stress inversions. The results show that the activity of these swarms is intense and short-lived, and is dominated by left-right lateral slip events on the east-west and northwest lines, respectively. In this study, we try to observe that most of the earthquakes occurring in the region exhibit considerable gradient variation in the Vp/Vs ratio. In addition to using the variation of normal stress, in the future, we will try to use FMT（focal mechanism tomography）to convert it to pore water pressure to observe its divisional variation and compare it with the former.

Since the collision is still active, this compression-generated microseismic may be related to the E-W or NW-SE pre-existing faults triggered by oblique slip faults. Therefore, the results of the study not only provide a better understanding of the seismogenic structures beneath the Foothill Belt in southwestern Taiwan, but also provide key information for the correct assessment of seismic hazard analysis in the metropolitan area.

Key words：Zhushan area, swarms, fluid diffusion, seiemic mechanism

Poster Code: P-07

Retrograde Slips on the Taiwan Deformation Front Triggered by 2016 ML 6.6 Meinong Earthquake

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On 6 February 2016, the magnitude (ML) 6.6 Meinong earthquake ruptured an unknown structure under the southwestern Taiwan with depth of 14.6 km. The surface ruptures recorded by the Interferometric Synthetic Aperture Radar (InSAR) showed abnormal eastern displacements (retrograde) on the Hsinhua fault nearby and north and south of the Guanmiao town. In this research we bring out the dense campaign mode GNSS data combine with InSAR results to explore the mechanisms of the retrograde deformation and the unknown structure located on the Hsinhua fault nearby. We also provide high-rate GNSS data showing the kinematic process of the retrograde surface deformation during the Meinong earthquake. The coseismic displacement field combined with GNSS and InSAR data presents a 2-3 kilometers × 8 kilometers retrograde displacement area striking with 74˚. NW-SE extension and SE-WNW compression observed on the western and eastern boundaries of the retrograde area, respectively. This result is corresponding to the WSW striking Napalin backthrust which roots on the Tainan detachment fault at a depth of ~4 km. The mechanisms of the retrograde displacement could be explained by strain localization on a critically stressed compliant fault zone. If the fault zone presents relatively low shear modulus and is close to failure, then it will rupture with the same polarity corresponding to the Coulomb stress change when the nearby earthquake occurred. The boundary between the backthrust and the Tainan detachment fault may relatively reduce the shear modulus and cause the strain localization. The Coulomb stress change contributed by Meinong earthquake also suggests the backthrust to failure. The high-rate GNSS data show whether the site located on prograde or retrograde displacement area, the permanent displacements are occurred after the P-wave arrived 10-15 seconds and all the sites gradually become stable.

Keywords: triggered slip, retrograde displacement, backthrust, Coulomb stress change, high-rate GNSS

Poster Code: P-08

Imaging the Shallow Subsurface Structure of Tainan City, Taiwan, Using Microtremor Data

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Tainan is the fifth largest metropolitan city in Taiwan. The most densely populated areas of Tainan incidentally spread across four topographic regions, from east to west, the Chungchou tableland, the Dawan lowland, the Tainan tableland and the Anping plain, respectively. Past studies have pointed out that topography and subsurface structures profoundly influence the levels of ground shaking when large earthquakes occurred. During the 2016 Meinong earthquake, the distribution of disasters was not only along the source rupture direction, but also at the edge of the Tainan tableland and the Dawan lowland, respectively. However, the seismic stations in the Tainan metropolitan area are not densely located, especially in the Dawan lowland, where seismic observation data are lacking. It hinders the possibility of exploring the causes of the disaster in this area through ground motion data. Therefore, for a more detailed and comprehensive assessment of the seismic hazard potential under different topographic divisions, we deployed microtremor array measurements to obtain shallow velocity structures at 52 locations in the Tainan metropolitan area. According to the velocity results, the variation trend of velocity at the site can be roughly classified by topographic division. At a depth of 1500 meters, the Anping plain has the lowest S-wave velocity, while the Tainan and Chungchou tablelands have relatively high velocities. The Dawan lowland, in the middle of the two tablelands, also has a lower S-wave velocity. This result is highly correlated with past geomorphological changes in the Tainan coastal plain. The ground motion simulation results show that the estimated peak ground velocity in the Dawan lowland is twice as high as that in the Tainan tableland area. Moreover, due to the combination of the rupture directivity and site effects, ground motion amplification reached 3-5 times in the 2016 Meinong earthquake disaster area. Our research complements the lack of seismic observation data in the Dawan lowland. It also points out that the threat of future earthquake disasters within the Dawan lowland is more significant than in other places in Tainan.

Poster Code: P-09

An Enhanced Procedure for Simulating the Stochastic Ground Motion

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The shaking map of the earthquake scenario provides valuable information for earthquake hazard prevention. A deterministic ground motion simulation can evaluate the ground motion parameters shown in shaking maps. It is made of synthetic broadband ground motion calculated by the hybrid technique based on assumed source parameters, e.g., magnitude, hypocenter, rupture speed, direction, specific asperity, and fault geometry. We developed a procedure based on MATLAB, Enhance Ground Motion Simulation Procedure (EGMSP), to conveniently generate these fault parameters for ground motion simulation. EGMSP included four main steps, (1) generate fault geometry and mesh to subfaults, (2) generate the characterized source model, (3) calculate the fault rupture time, (4) integrate and output source parameters. Moreover, we also developed a stochastic finite-fault simulation code (Enhance Ground Motion Simulator, EGMS) that can simulate the high-frequency waveform for the fault with a curve geometry. This program solved the problem that the current software (e.g., EXSIM, GMSS) can only apply to a simple plane fault geometry. The result allows the ground motion simulation reduces the spatial error due to the inaccurate fault geometry assumption.

Keywords: scenario earthquake, ground motion simulation, characterized source model, stochastic finite-fault simulation

Poster Code: P-10

New Empirical Source Scaling Laws for Crustal Earthquakes Incorporating the Fault Dip Angle and Seismogenic Thickness Effects

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We developed new global source scaling laws of crustal earthquakes by considering the effect of the fault dip angle (ν) and bottom depth of the seismogenic zone in detail, in which the bottom depth effect consisted of the regional term and a normalized hypocenter depth term. In contrast to the commonly used Mw to fault length (L), width (W) and area scaling relations, we connected the Mw to the aspect ratio (L/W) and to the fault area simultaneously to control the main behavior that the aspect ratio would increase when a circular-expanded fault source grows toward a depth limit (bottom of the seismogenic zone). A globally finite fault solution data set from multiple references, such as the Earthquake Source Model Database (SRCMOD) and several extra Taiwan events, was collected to build the source scaling relation for crustal earthquakes in this study. However, scaling differences may be physically rely on the fault geometry but may not the rake angle on the fault and could be captured very well by the proposed aspect ratio scaling law by considering the geometry-related effects, such as the magnitude-dependent ν and bottom depth of the seismogenic zone. Furthermore, we selected the bilinear relation to build the matched area scaling law, and it generally behaved similarly to the scaling in previous area-Mw studies. Finally, the corresponding L and W scaling results obtained by converting the area and aspect ratio to L and W showed good agreement with the previous regional scaling laws.

Poster Code: P-11

Analysis of the TEM Long-term Slip Fault Rates and Distributed Deformation Rates in Taiwan Orogenic Belt by Finite-element Kinematic Model

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This study used kinematic finite element code to estimate the long-term slip rate of faults and the distributed permanent strain rate to assess the seismic hazard model in Taiwan orogenic belt.

The community data sets include TEM inland seismogenic structures (Shyu et al., 2020) and offshore seismogenic structures mapped by Chen and Shyu (2022). The initial input parameters of each inland fault (fault dip, rupture depth, and long-term slip rate) were used by Shyu et al. (2020). We also considered the oblique slips for some active faults. The principal stress direction data obtained from Dr. Heidback (the first author of Stress Map of Taiwan 2022). He helped us to estimate the mean SHmax orientation on 0.1° grid using only data shallower than 20 km depth. We interpolated these stress directions into each finite element. The 2002-2020 interseismic horizontal GNSS velocities which were removed the velocity fields on fault grids and non-tectonic velocities. The plate boundary and Euler pole used the default PB2002 data.

Our simulation results showed that the Chaochou fault and the Kaoping River structure in southwestern Taiwan have high left lateral rates, and the Youchang structure and the Chishan fault have high right lateral rates, which are consistent with recent observations.

In this study, the offshore seismogenic structures were added, and the simulation result also showed that some offshore structures contribute to higher slip rates. It may be used as the key sources for the following PSHA.

Poster Code: P-12

Estimation of Current Earthquake Hazard through Nowcasting Method: A Case Study from Taiwan

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In several tectonically active regions of the world, large magnitude earthquakes on fault systems are observed to occur in near-repetitive cycles as a consequence of stress accumulation and moment release. Since absolute measurements of stress-strain is unavailable through direct observations at all regions of interest, the area-based nowcasting method based on earthquake data is a potential alternative to estimate the uncertain current state of earthquake hazard in a defined region. Using the concept of natural-time counts, the nowcasting result comprises time-dependent earthquake potential score – a numerical quantification of earthquake-cycle progression since the last major event in the region. The nowcast score may be linked to the instantaneous risk of large events. This paper summarizes some basic formulation and key concepts of earthquake nowcasting with a demonstration of its applicability in disaster preparation and risk estimation. A case study from the cities in Taiwan is considered for illustration.

Keywords: Earthquake nowcasting, Taiwan, Natural times, Hazard analysis

Poster Code: P-13

Statistical Analysis of Fault Dip Distribution and Corresponding Weights

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The fault trace, dip, and seismogenic depth are usually used to define the fault geometry. The fault dip is one of the key parameters representing fault geometry used in a probabilistic seismic hazard assessment (PSHA). However, the results of various investigations show the varied dipping angle along the faults. Subjective evaluation happens when experts judge the dip parameters by reference to their perspective.

In this study, I explore how to improve the fault dip evaluating process into a fault model for PSHA. The statistical analysis is used in evaluating the fault dip process to exclude subjective bias. The dip frequency histogram with a well-fitting normal distribution curve indicated the dips distributed approximately normally. We can easily define the required 68.3% and 90% confidence intervals, corresponding to ±1σ and ±1.6σ (σ= standard deviation) for the normal-distributed estimator and give weights 0.3/0.4/0.3 and 0.2/0.6/0.2 respectively (Fig. 1).

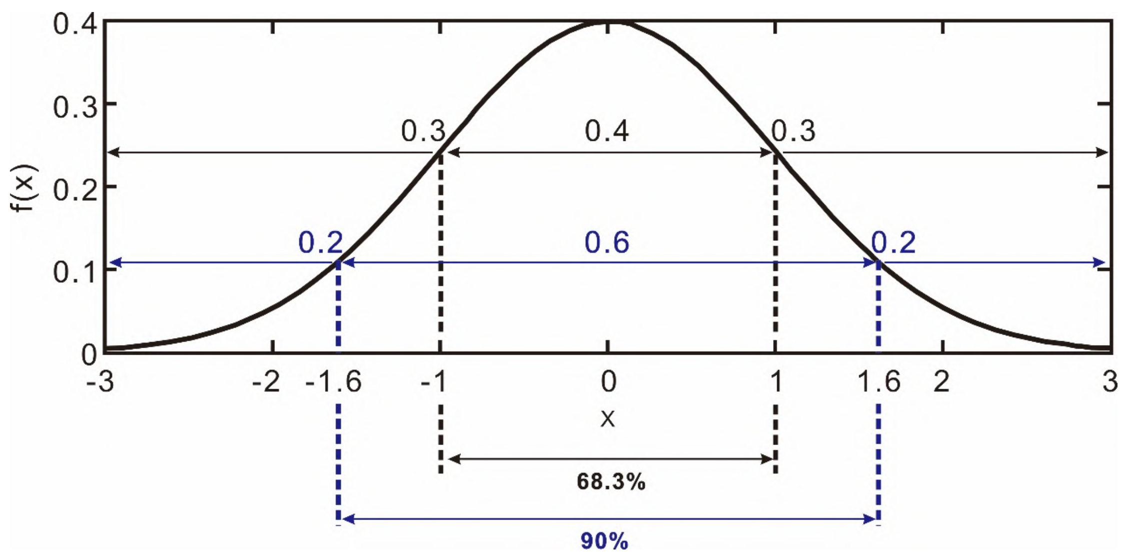

Figure 1. Probability within required confidence intervals of a normal distribution (Modified from Winter, 2015).

Based on the analysis, the dip branch of Chishan fault is estimated to be 46°/61°/76° with 0.3/0.4/0.3 or 38°/61°/84° with 0.2/0.6/0.2 (Fig.2a); the dip branch of Choukou-Lunhou fault is estimated to be 32°/45°/58° with 0.3/0.4/0.3 or 24°/45°/66° with 0.2/0.6/0.2 (Fig.2b).

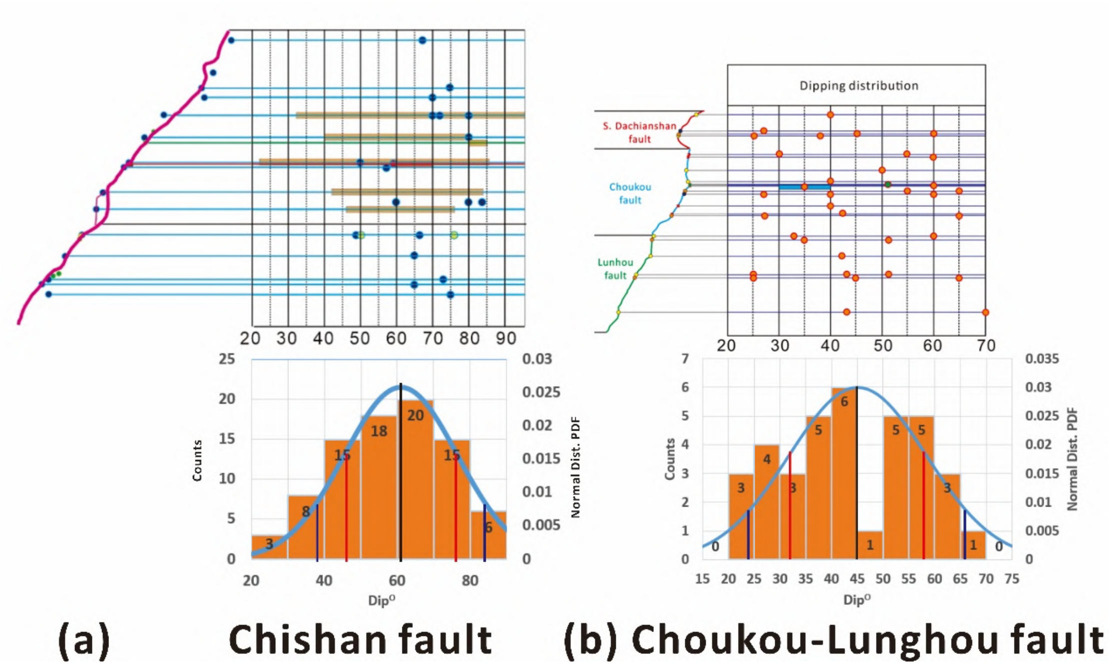

Figure 2. The dip frequency histograms with well-fitting normal distribution curves of (a) Chishan fault and (b) Choukou-Lunhou fault.

This preliminary study provides an approach for better evaluation of the dip parameter and their weights in the fault model for PSHA. However, this approach is only applicable to structures with simple geometry, sufficient investigations and well-documented data. For structures with complex geometry (listric or multiple dip angles) or with inadequate data, this approach may not be appropriate.

Poster Code: P-14

Contemporary Seismic Moment Budget along the Nepal Himalaya Derived from High-resolution InSAR and GPS Velocity Field

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Throughout history, a number of large-magnitude earthquakes have caused damage to the Himalayan region and humanity. This study estimates the contemporary seismic moment budget along four spatial blocks over the Nepal Himalaya. For this, (1) we integrate the InSAR and GPS observations to derive a high-resolution velocity field; (2) we then calculate strain-rate distributions from the integrated velocity field, and (3) finally, we compare the geodetic moment accumulation estimated from strain tensors and seismic moment release based on an earthquake database of 900 years. We find that the geodetic strain is not homogeneous over the Nepal Himalaya, rather the regions near the Main Central Thrust and western Nepal have significantly higher strain rates. The geodetic moment rate across various blocks ranges from 8.959×10^18 Nm/yr to 13.024×10^18 Nm/yr, whereas the seismic moment rate varies between 5.934×10^17 Nm/yr and 24.46×10^18 Nm/yr. The associated moment deficit rate indicates that in two blocks, namely the western Nepal and the block containing Kathmandu as well as the epicenter of the 2015 Gorkha earthquake have an earthquake potential of magnitude M_w 8.0 and M_w 8.3, respectively, while the other two blocks including the eastern Nepal have no contemporary earthquake potential. In summary, the present study contributes to the time-dependent earthquake hazard analysis along the Nepal Himalaya using the state-of-the-art high resolution InSAR and GPS velocity field.

Poster Code: P-15

Natural Hazard Risk Assessment Through High-resolution of Building Inventory Database

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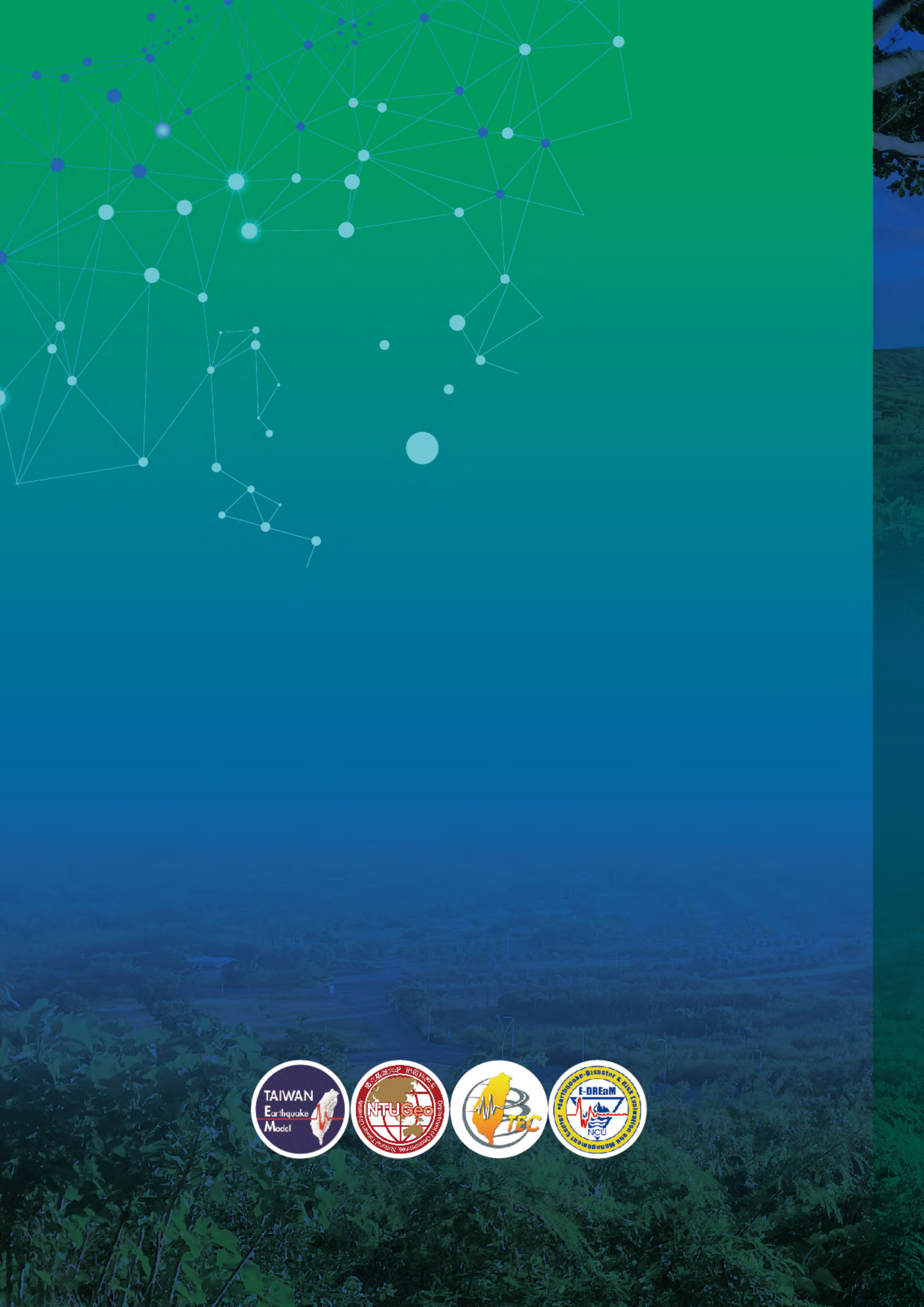
Developing building exposure, vulnerability, and the hazard model for natural hazard risk assessment have been the focus topic for urban development and future design by understanding and strengthening societal capacity for resilience. Transparent exposure model has become a tendency under the modern open data era in recent decades. An exposure model is defined by spatial distribution of buildings, which is characterized in terms of building taxonomy, building height, construction times and the number of residential, industrial and commercial buildings. The major challenge to the establishment of exposure model, especially with transparency, including detailed building information mentioned above is the data acquisition. The Volunteered Geographic Information data can certainly supply it but their type of information is usually limited and, therefore, insufficient to generate an exposure data set. The governmental tax data contain sufficient information, however, difficult to obtain owing to confidentiality of the data. Thus, how to efficiently establish exposure model from different dataset plays an important role for risk assessment. Current risk assessments were mostly made by considering the building resolution in administrative unit or grid-based. Obtaining detailed information of every individual building in a large region is not practicable. The scarcity of building information is not compatible with the level of detail necessary to accurately model the risk. To provide a risk assessment from a more dynamic exposure model, by comparing with the assessment of scenario-based loss estimation with the exposure model of 500x500 meter grid-based data from the National Science and Technology Center for Disaster Reduction, we constructed an exposure model for Taipei City taking building as the statistical unit according to the government tax data from finance statistics database. In addition to the improvement of the datasets, we prioritize the impact to the risk modeling by assessing additional resources contributing to the exposure model. In this work, we propose the flowchart to discuss the data completeness from difference sources in building dataset and the procedure for the combination of the data to establish the exposure database for Taipei city. At a regional level, we build this database in a dynamic fashion, such that it could be updated accordingly once new datasets, feedback, and models become available. Preliminary studies show that the current Volunteered Geographic Information (VGI) data in the Taipei city efficiently provides building information and building polygon for each individual building. The government open data with detail building information improves completeness of the data. The government tax data is the most comprehensive dataset for the establishment of exposure model. Based on the procedure, we build the Taipei City exposure model. This up-to-date, open, transparent and reliable risk-database ensures effective disaster response in the future.

Keyword: hazard, risk, exposure model, building inventory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