Workshop on Seismic Hazard Assessment Issues in the island arc of Taiwan and Japan
June 4-6th 2012, NCU, Taiwan

Earthquake probability mapping and hazard mitigation program in Taiwan

K. L. Wen[1,2], T. H. Wu[2], B. R. Wu[2], M. W. Huang[2], S. Y. Liu[2], and C. L. Chang[2]

1) Institute of Geophysics, National Central University, Taiwan
2) National S&T Center for Disaster Reduction, NARL, Taiwan

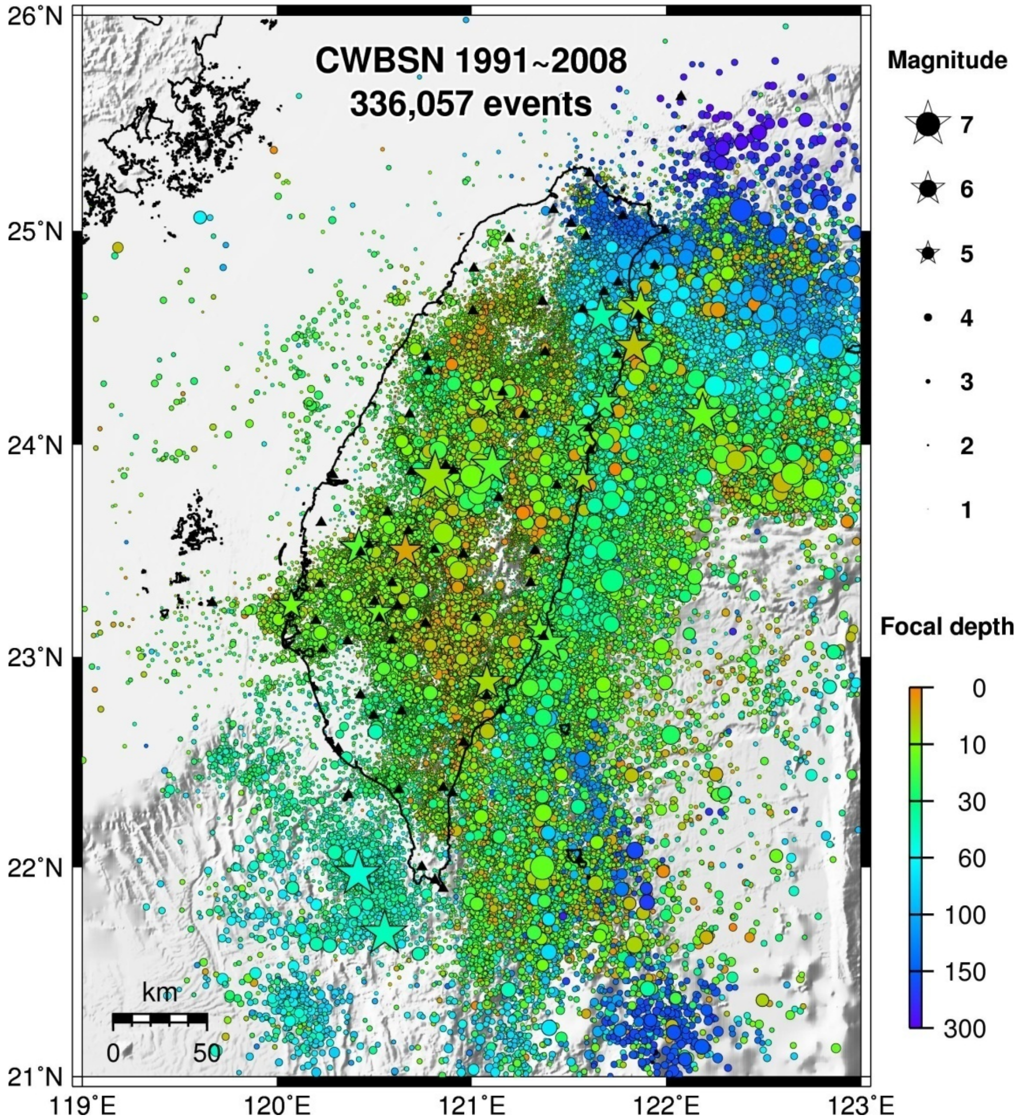
國家災害防救科技中心
National Science and Technology Center for Disaster Reduction

Outline

- **Hazard Mitigation Planning for Large-scale Earthquakes**
  - **Priority Regions of Earthquake Disaster Prevention**
- **Probabilities of the Potential Earthquakes – Regional Source**
  - **Shallow zone：12 zones**
  - **Deep zone: 4 zones**
- **Operation of Emergency Response**
  - **Support Central Emergency Operation Center (CEOC)**
- **Promotion of Earthquake Early Warning**

Hazard Mitigation Planning

Taiwan has experienced ten destructive earthquakes with magnitude greater than 6.0 almost in every decade since the 1900s. It is essential to organize a comprehensive hazard mitigation plan for reducing the losses induced by large-scale earthquakes.



data from CWB

Priority Regions of Earthquake Disaster Mitigation

Due to the limited time and cost, it is suggested to consider the regions with serious destruction induced by large-scale earthquakes first. Those regions with the following characteristics should be assigned as the Priority Regions.

1. Political and Economic importance.
2. High potential of earthquake and disaster.

Priority Regions of Earthquake Disaster Prevention

When promoting large-scale earthquake disaster prevention works, priority is given to regions with political and economic significance, as well as higher earthquake potentials. They ought to be designated as "Earthquake Disaster Prevention Priority Regions".

Earthquake Disaster Scenario Simulation

After designating the priority regions, use the "earthquake disaster scenario simulation method" to assess the possible losses in these regions.

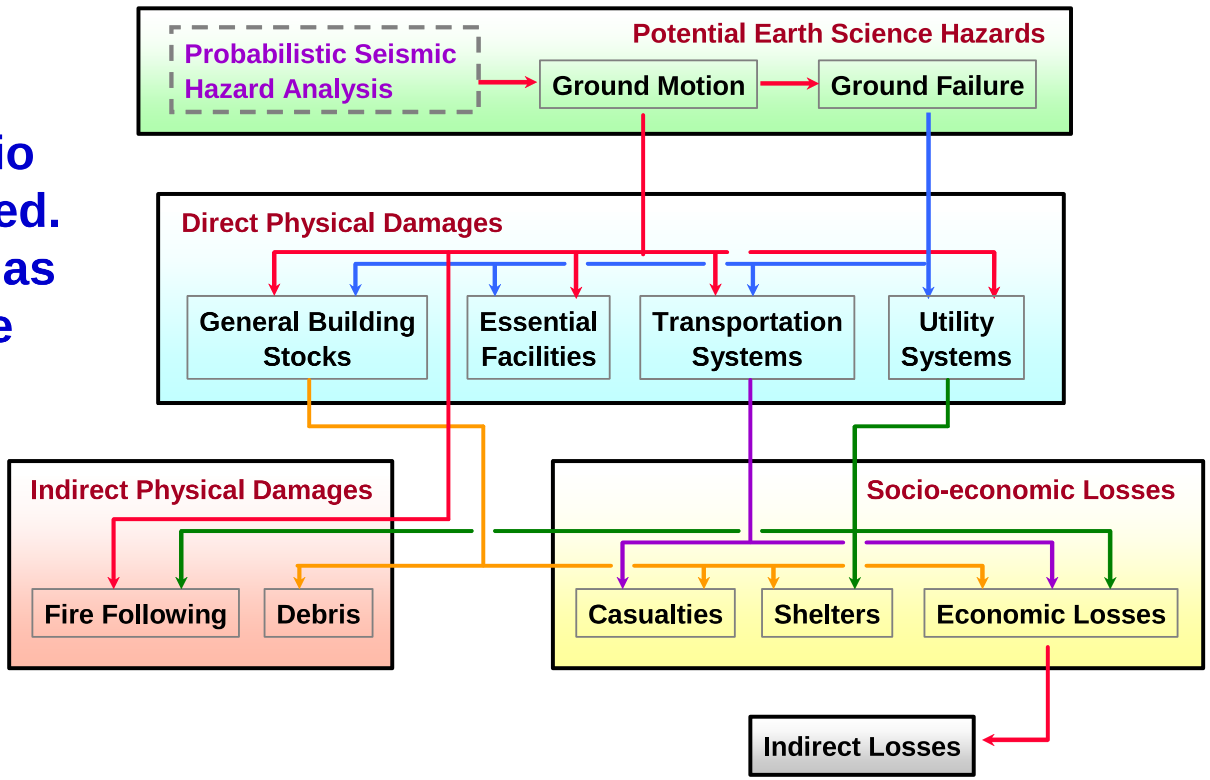
Earthquake Disaster Mitigation Strategies

Based on scenario simulation results, propose "earthquake disaster mitigation strategies" for each priority region.

Earthquake Disaster Scenario Simulation

The natural conditions, humanity characteristics, and geography features of regions are the import factors to be considered in the seismic scenario simulation. With the seismic scenario simulation technology, the casualties and damages induced by various scenario earthquakes can be obtained. Those results can be used as the basis for organizing the hazard mitigation plan.

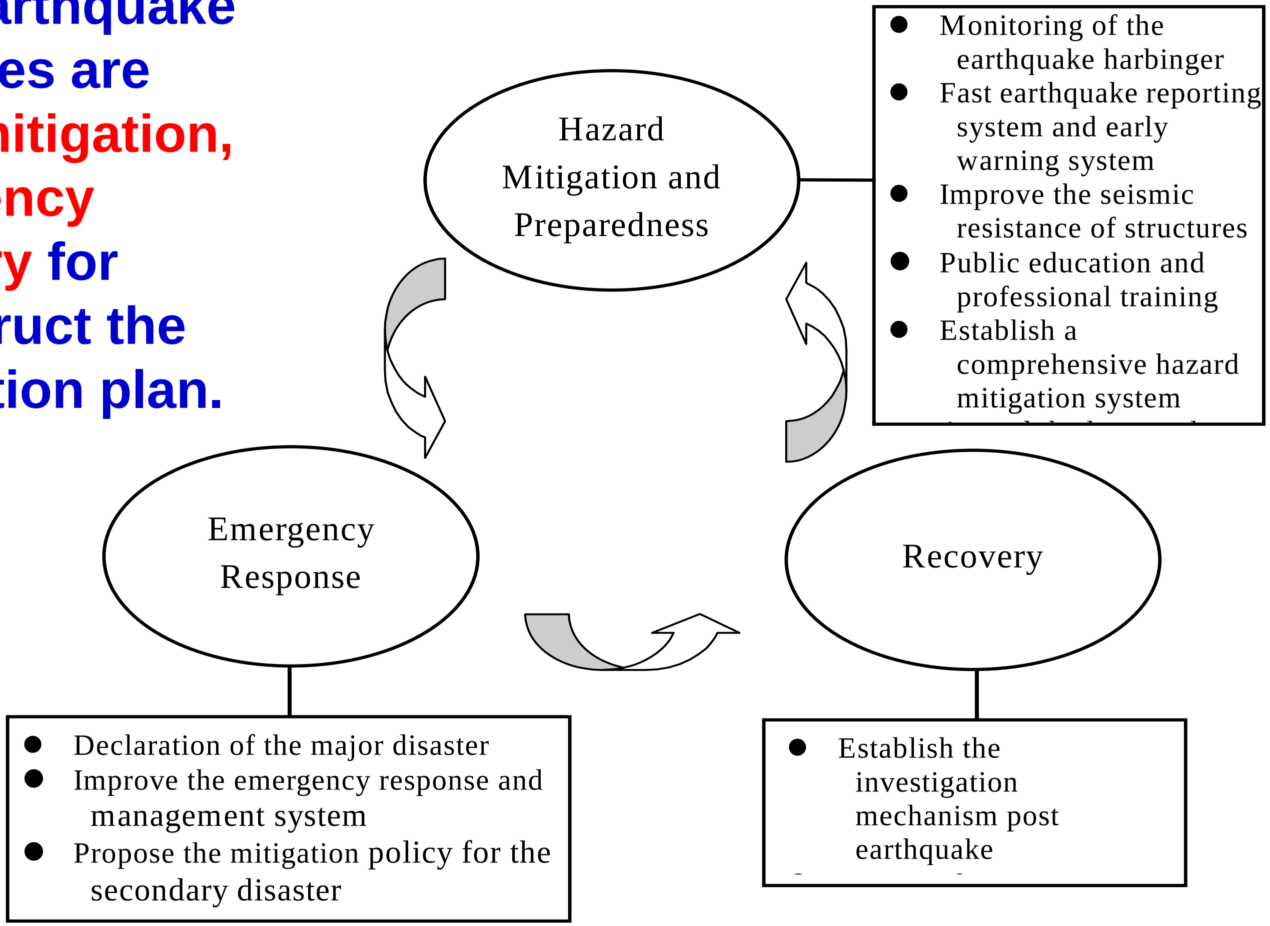
Framework of the Taiwan Earthquake Loss Estimation System



Earthquake Disaster Mitigation Strategies

According to the scenario simulation results, the central and local governments can organize the corresponding policy to reduce the earthquake losses. Some strategies are proposed for hazard mitigation, preparedness, emergency response, and recovery for governments to construct the seismic hazard mitigation plan.

Earthquake Loss Reduction Strategy



Designation mechanism of priority region for seismic hazard mitigation

NCDR

Organize a working group for designation of priority region

- Assess fault parameters, earthquake potential and damages
- Suggest priority region for seismic hazard mitigation

1. Fault Parameter Forum

The Central Geological Survey invites scholars to determine fault parameters and propose a applicable version.

2. Earthquake Potential Forum

NCDR invites scholars to assess probability of potential earthquakes in 10 to 50 years and estimate earthquake ground motions.

3. Risk Evaluation Forum

NCREE invites scholars to determine risk evaluation model and risk index.

Propose applicable fault parameters → Evaluate probability of potential earthquakes and analyze earthquake ground motions → Investigate possible damages and losses in Taiwan

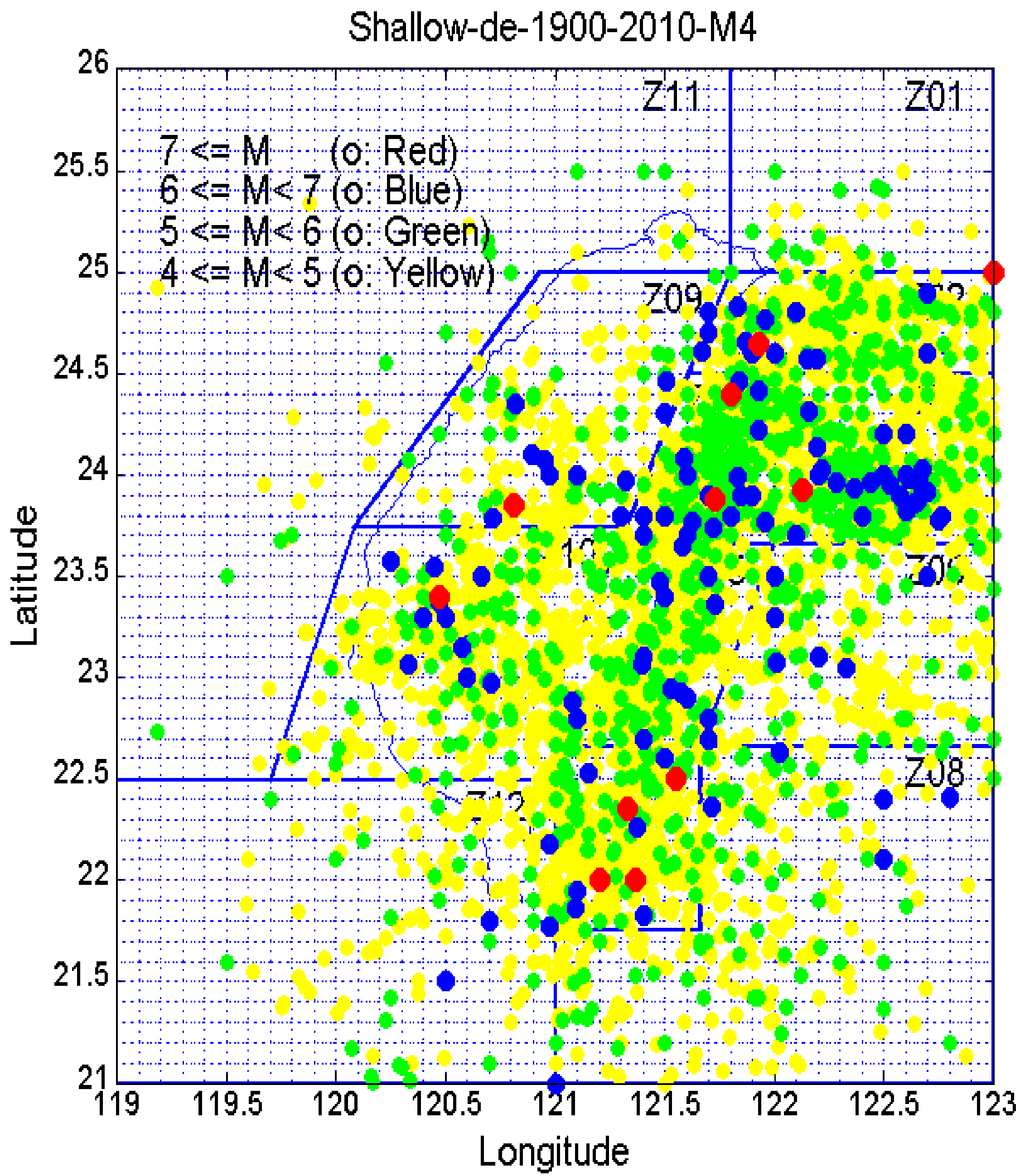
Outline

- **Probabilities of the Potential Earthquakes - Regional Source**
  - **Shallow zone：12 zones**

Assessment processes of evaluating the occurrence probabilities

- Regional source
  - Zoning and earthquake catalog
  - Remove the effect of aftershock
  - Magnitude of potential earthquake
  - Magnitude and frequency relationship
  - Recurrence Model

Regional Sources



Zoning

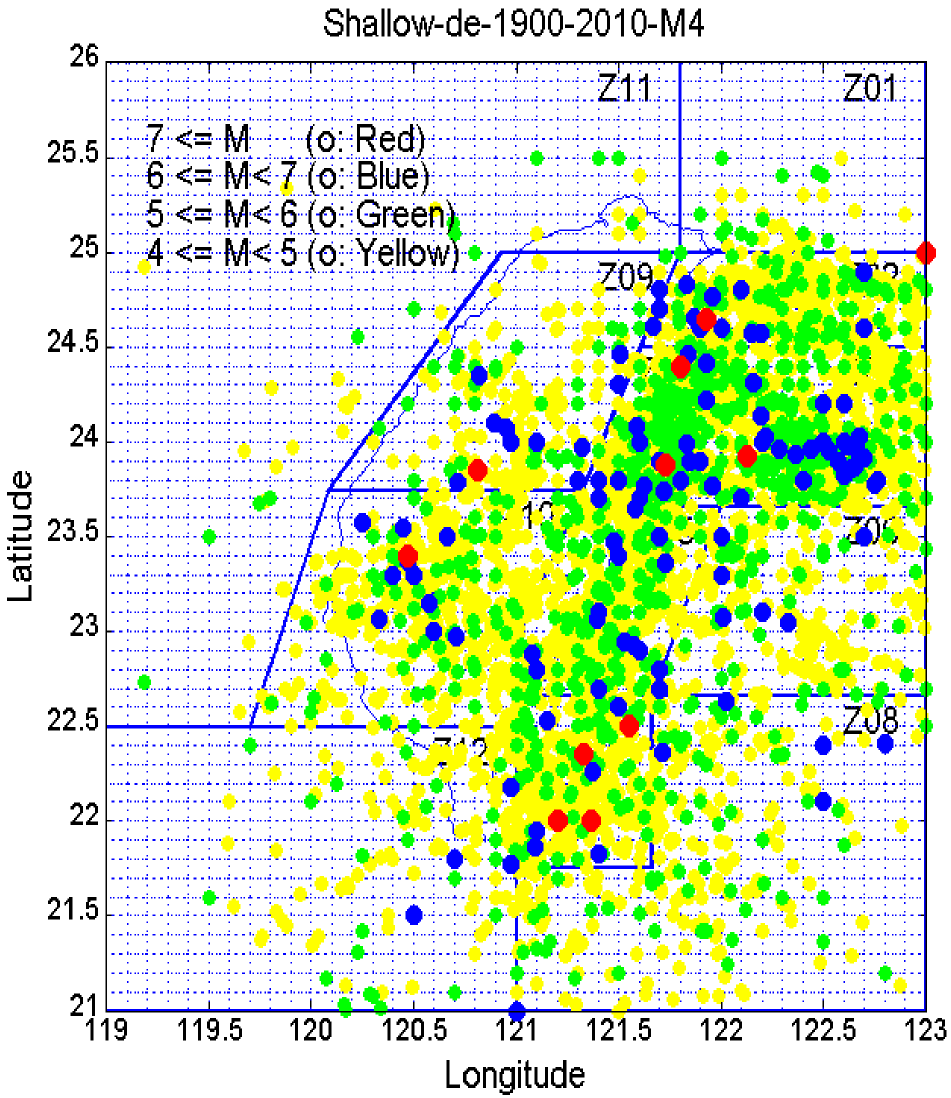
Geology

Seismicity

Red dots：

Epicenters（1900~2010/12, $M_L \geq 7$）

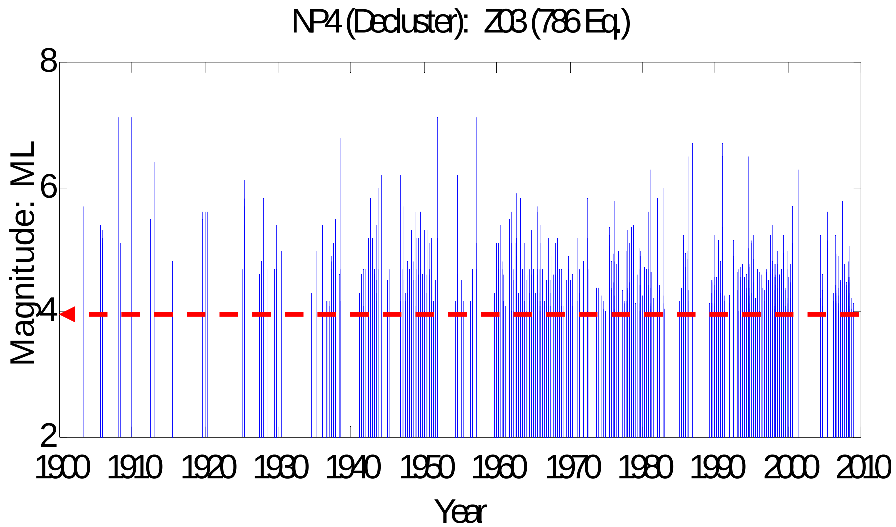
Earthquake Catalog



Catalog: 1900-2010/12

Magnitude: $M_L \geq 4$

Depth: D < 40 km



Remove the effect of aftershock

$$\mathrm{Log}(T) = a_1 M + b_1$$

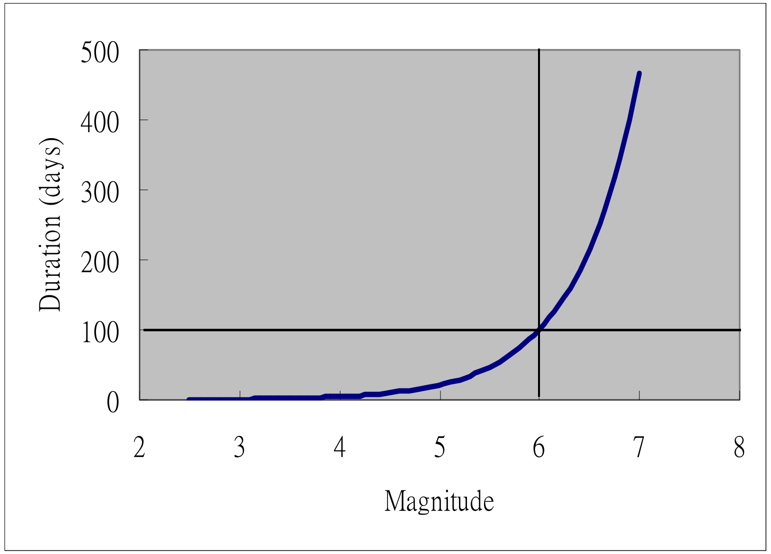
$$\mathrm{Log}(L) = a_2 M + b_2$$

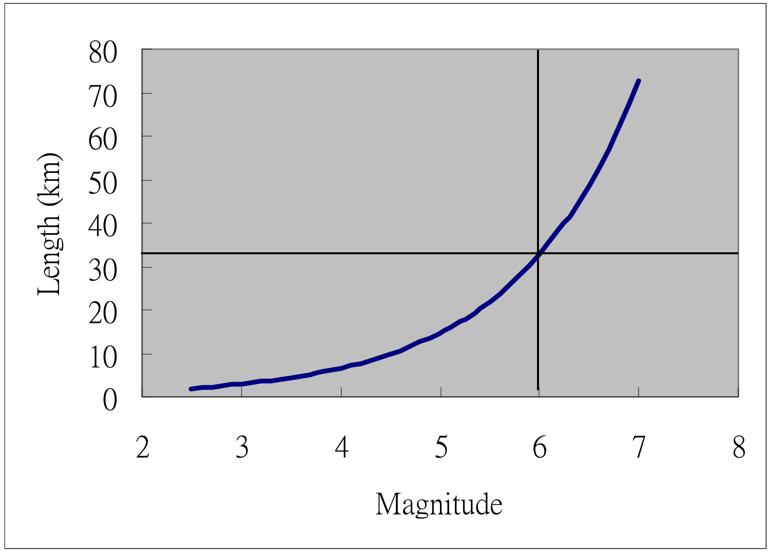
$a_1 = 0.668$

$b_1 = -2.007$

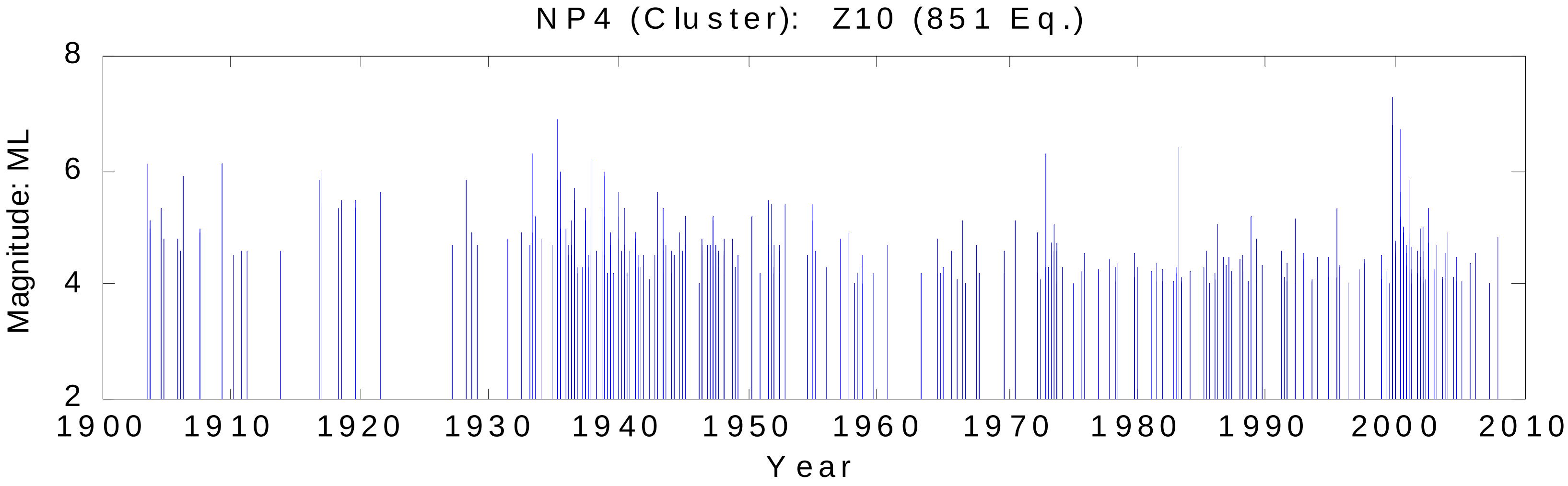
$a_2 = 0.347$

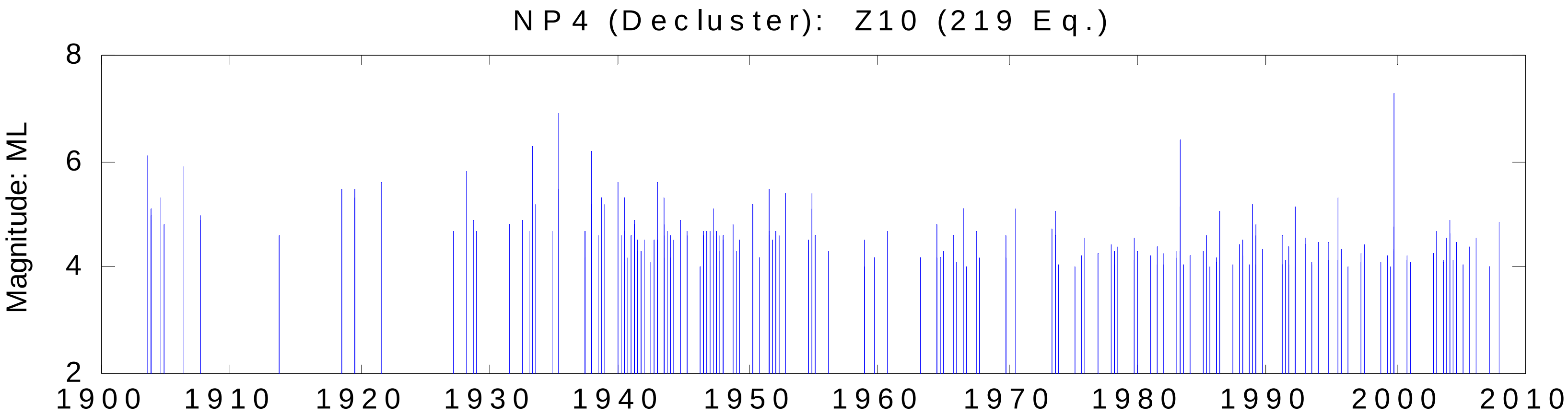
$b_2 = -0.567$





Catalog before and after removing aftershocks

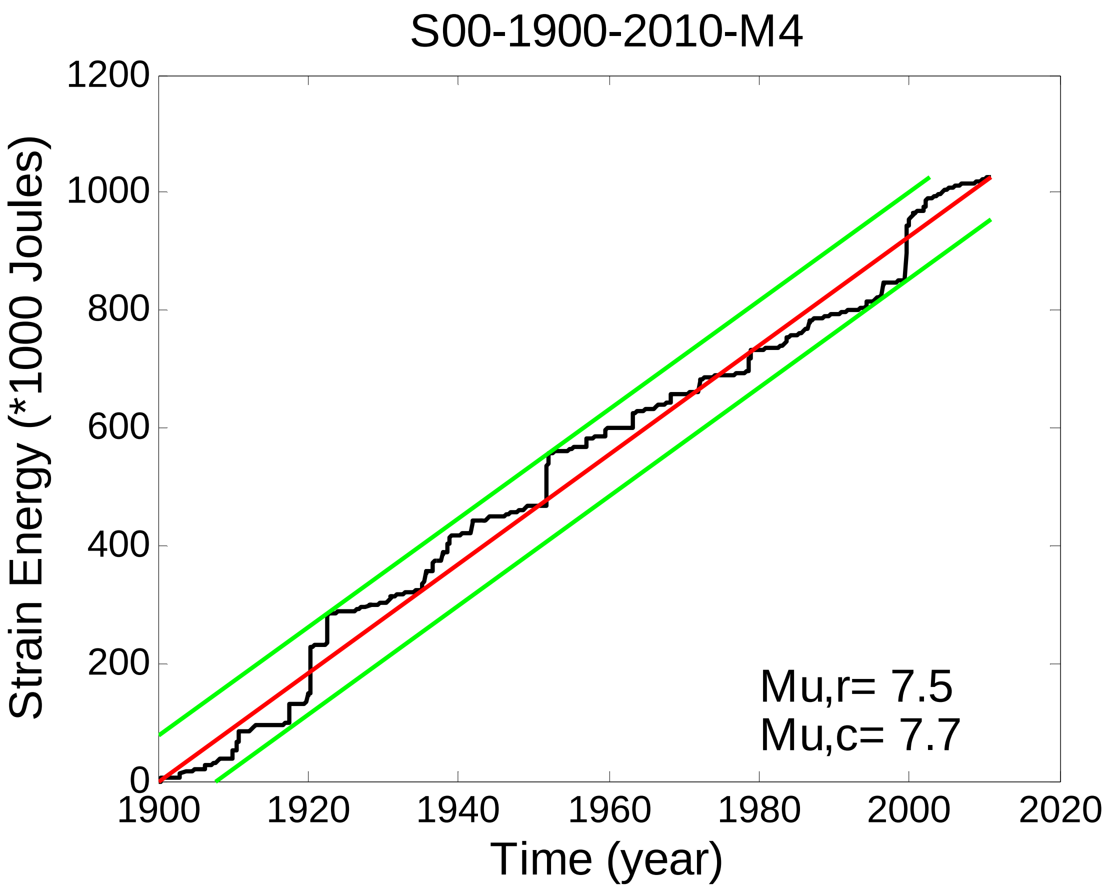




Max. Earthquake: Cumulative Energy Method

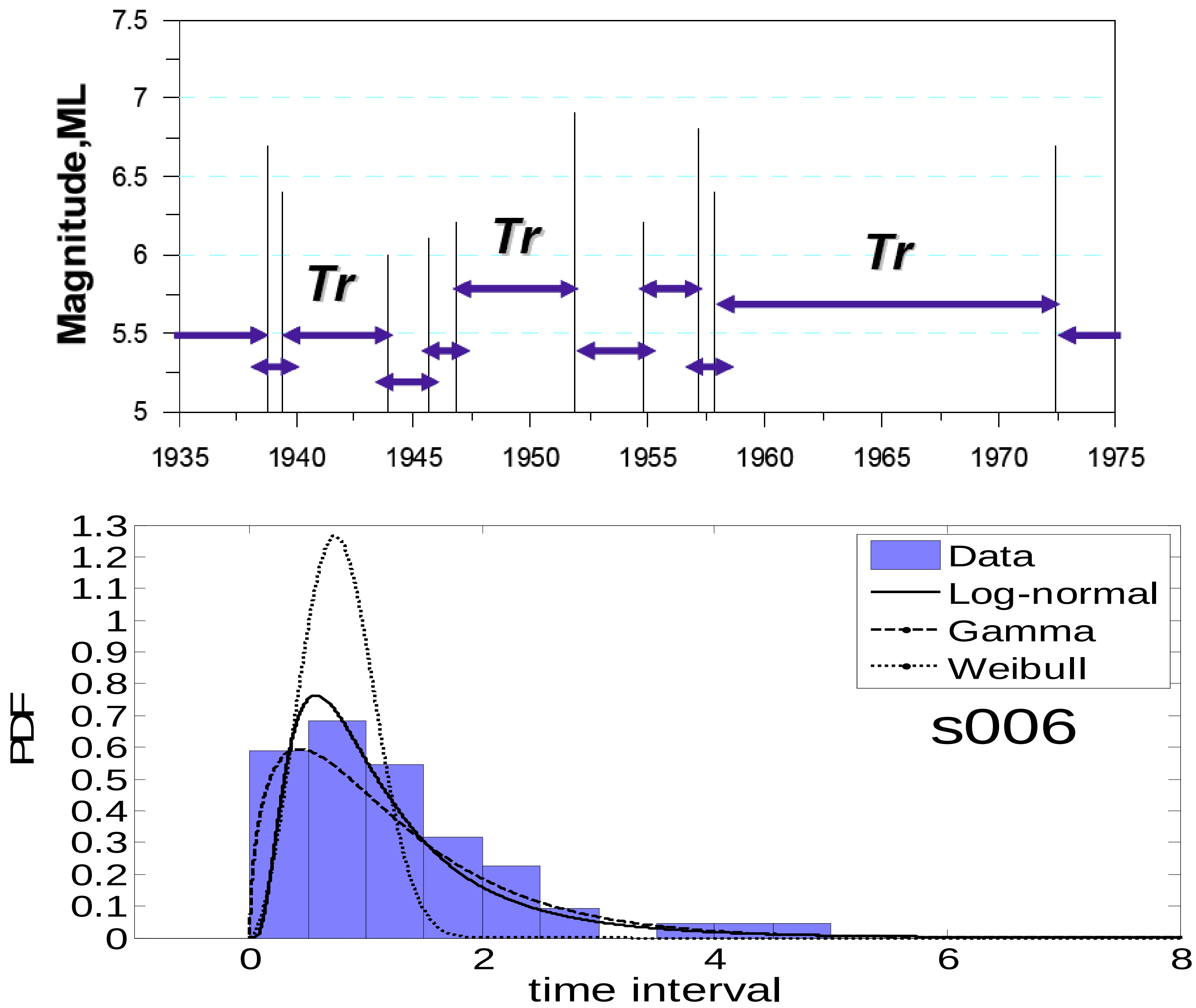
(Maxropoulos and Burton, 1983)

Taiwan Area



$\log E = 12.66 + 1.4M_L$ (Iida, K., 1976)

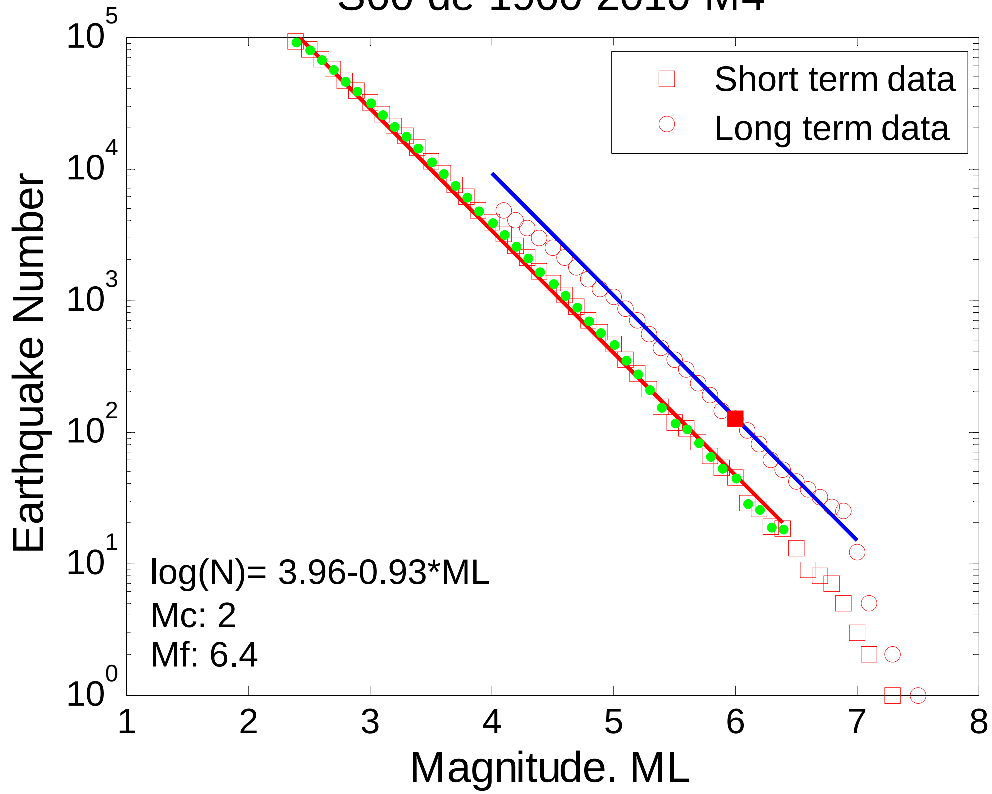
Distribution of Time Interval



Frequency and Magnitude Relationship (G-R Law)

Gutenberg and Richter (1944)

Taiwan Area



Least Square Method

(1) b value:

$M \geq 0$, 1973-2010/12

(2) a value:

$M \geq 4$, 1900-2010/12

Initial anchor point :

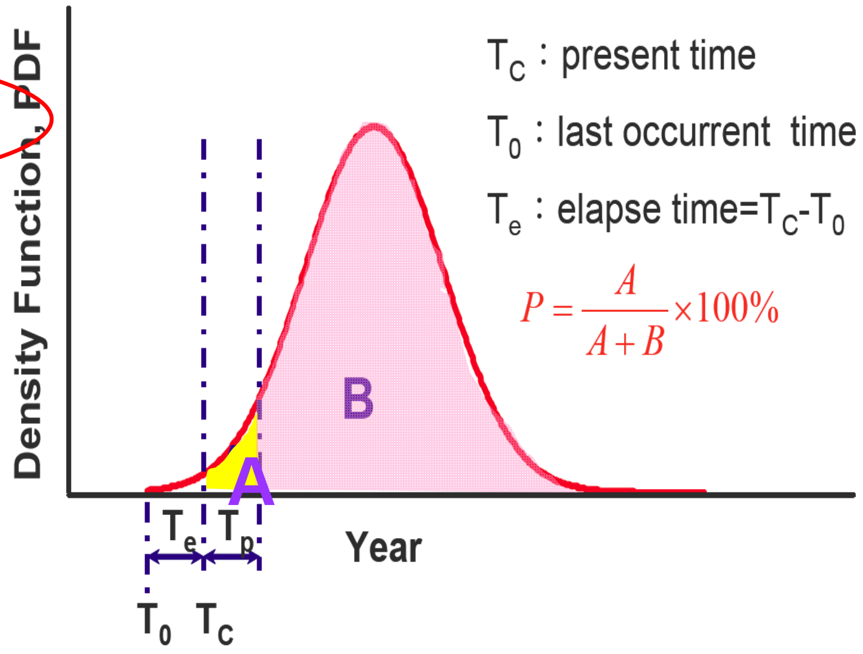
$M \geq 6$

$\text{Log}(N) = a - b\ M$

Probability Density Function (PDF)

Log-normal distribution

$$f(x;\mu,\sigma) = \frac{e^{-(\ln x-\mu)^2/(2\sigma^2)}}{x\sigma\sqrt{2\pi}}$$

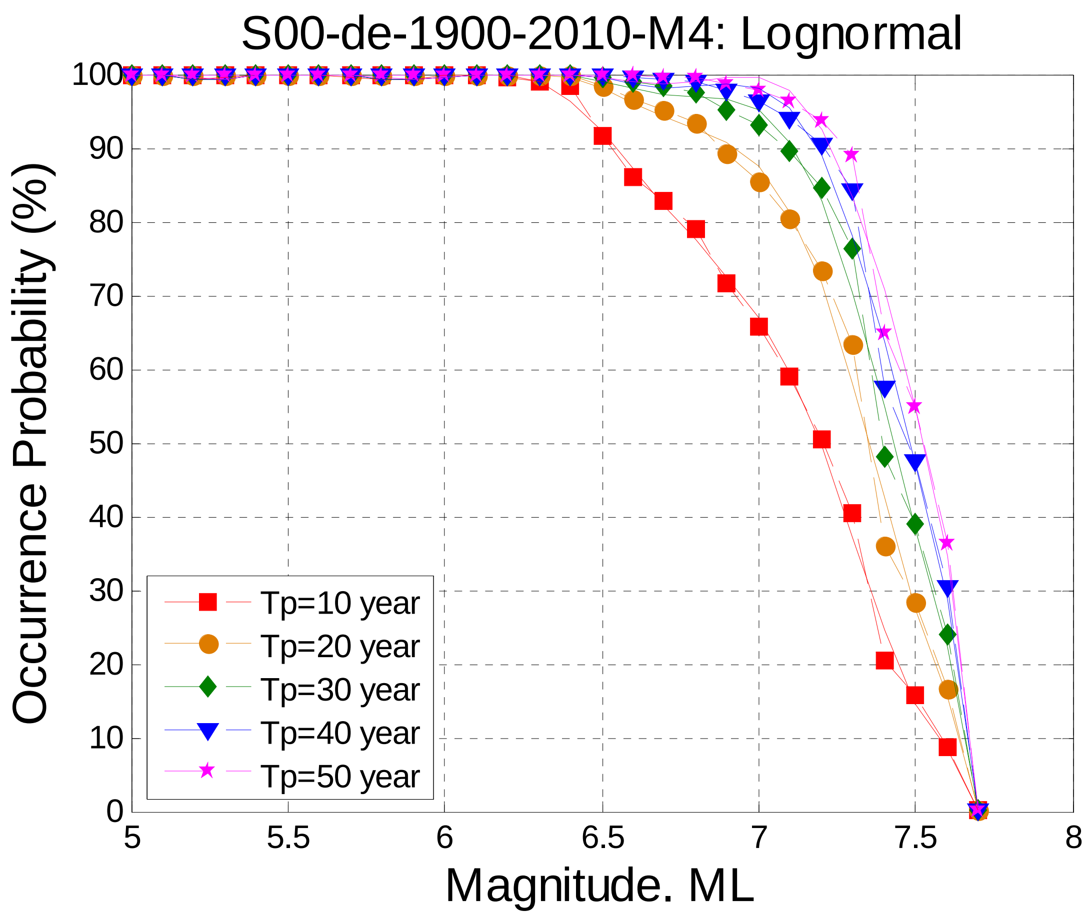


Recurrence Model: Conditional Probability Model

Probabilities in Next 10, 20 30, 40, and 50 Years

The conditional probability model with
log-normal distribution

Taiwan Area

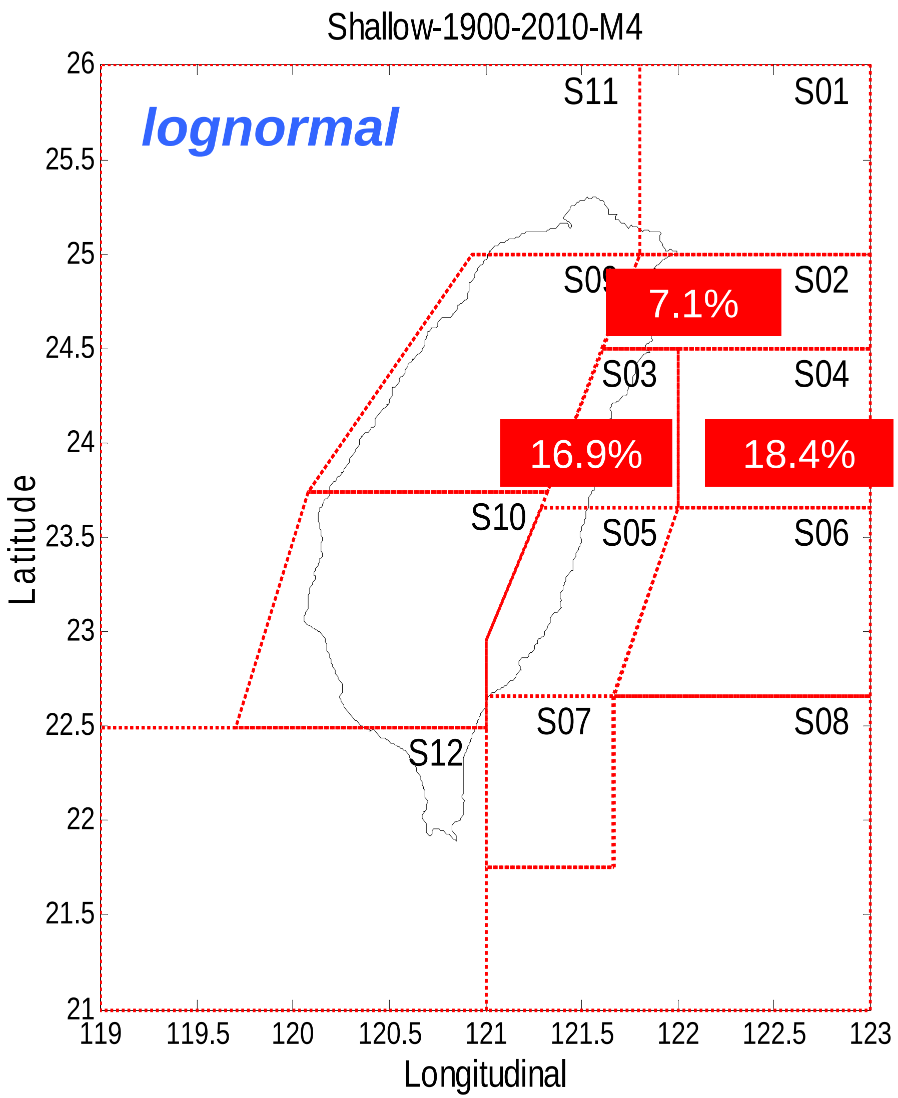


Probabilities (%) for $M_L \geq 6$, $M_L \geq 6.7$, $M_L \geq 7$

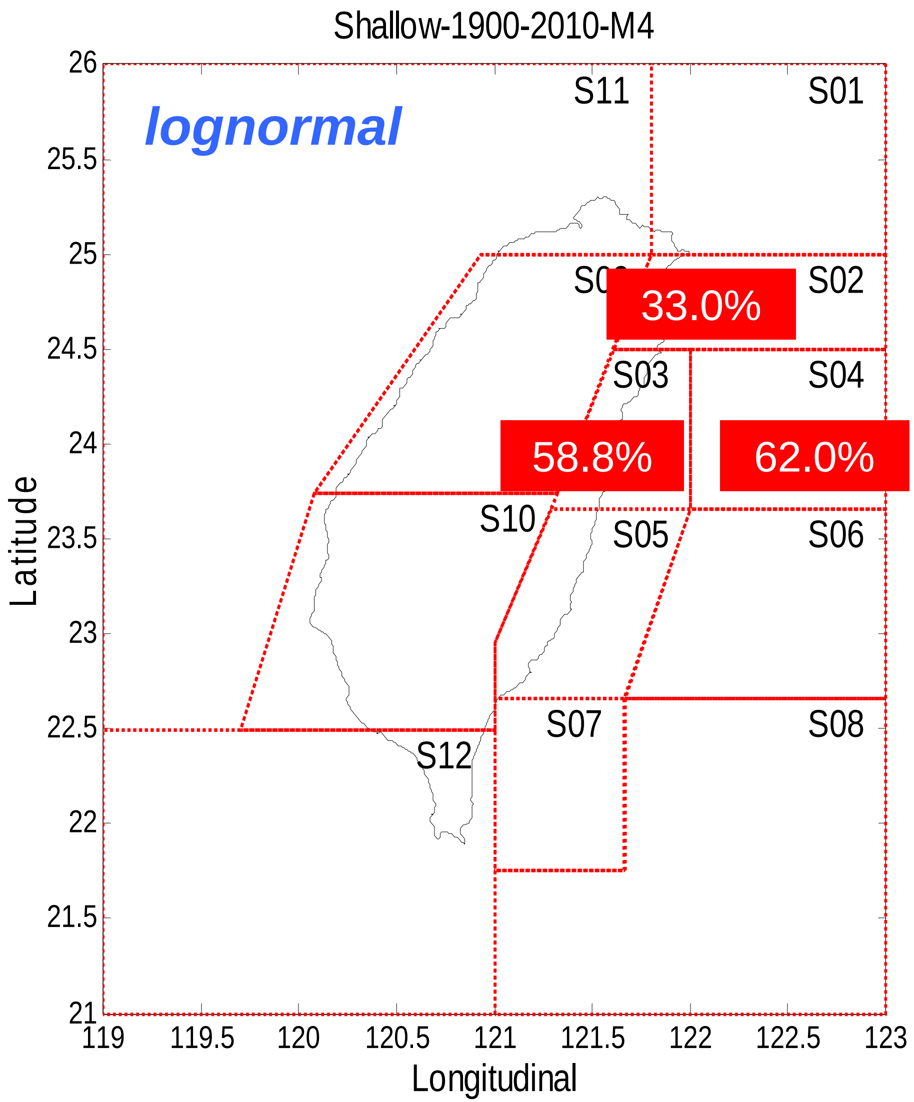
	M>6.0			M>6.7			M>7.0		
zone	10 year	30 year	50 year	10 year	30 year	50 year	10 year	30 year	50 year
Taiwan	99.8	99.9	100	82.3	97.2	98.6	67	95	99.7
S01	25.9	59	76.7	1.3	5.4	10.6	0.3	0.3	0.2
S02	68	94.6	98.7	18.9	46.2	63.6	7.1	20.8	33
S03	84.1	98.8	99.7	34.7	70.6	85.3	16.9	41.8	58.8
S04	90.7	98.9	99.5	48.4	81.4	91.3	18.4	45.4	62
S05	84.4	99.2	100	16.1	54.2	77.5	0.2	5.7	17.7
S06	65.9	94.9	99.1	13.9	40.3	59.9	0.01	0.1	1
S07	79.4	98.3	99.5	9.1	40.2	65.4	0.2	2.1	9.4
S08	69.2	96.4	99.8	12.7	32.2	45.8	-	-	-
S09	31.8	75	89.1	2.2	11.6	22.8	0.1	0.9	3.1
S10	64.3	95.2	99.1	16.4	38	53.8	2.8	12	20.1
S11	-	-	-	-	-	-	-	-	-
S12	38	74.3	88.3	5.6	18.1	29	0.01	0.01	0.3

lognormal

Prob. of $M_L \geq 7$ in next 10 yr

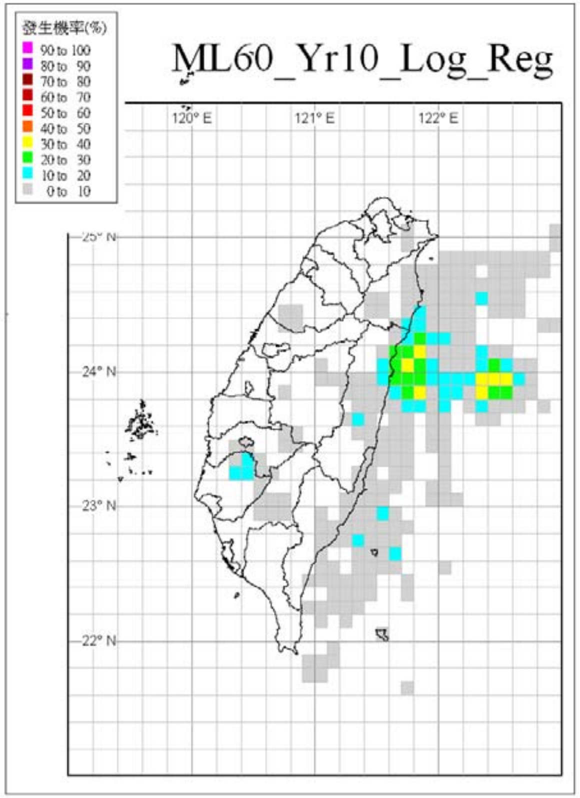


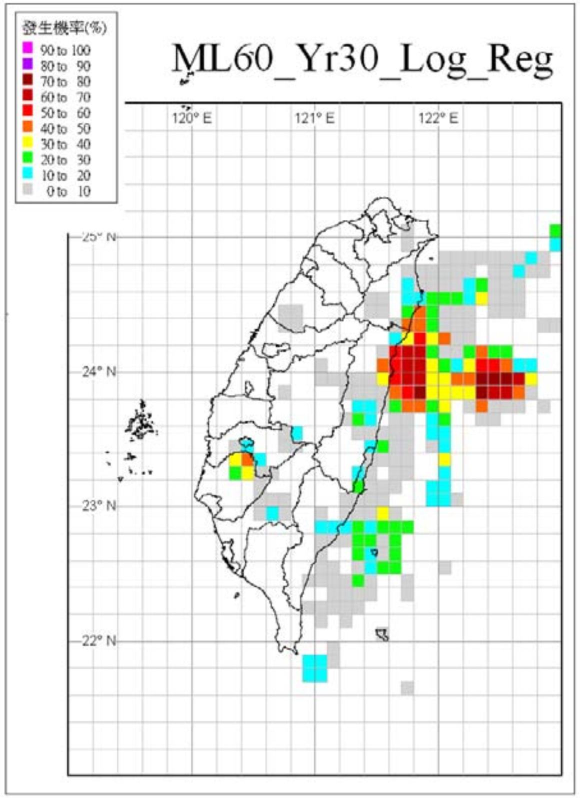
Prob. of $M_L \geq 7$ in next 50 yr

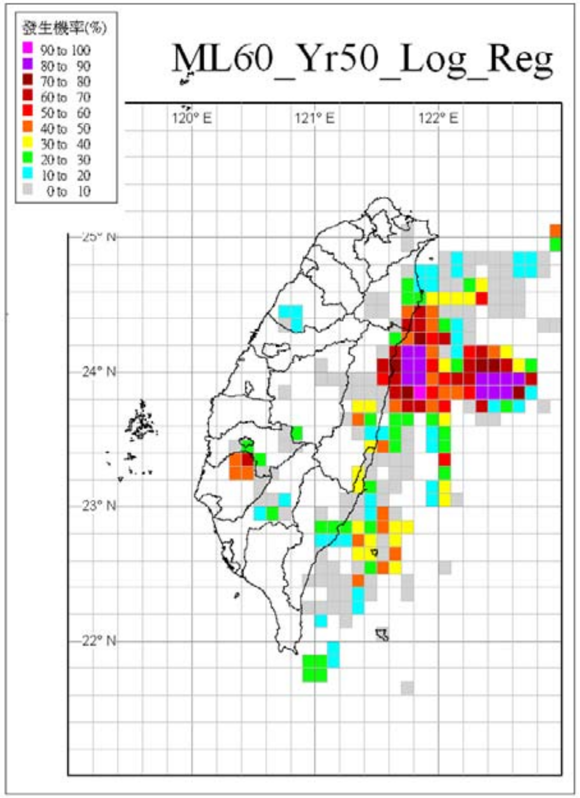


Recurrence Probabilities Utilizing Micro-zoning Method

Probabilities(%) for $M_L \geq 6$ in next 10, 30, 50 years

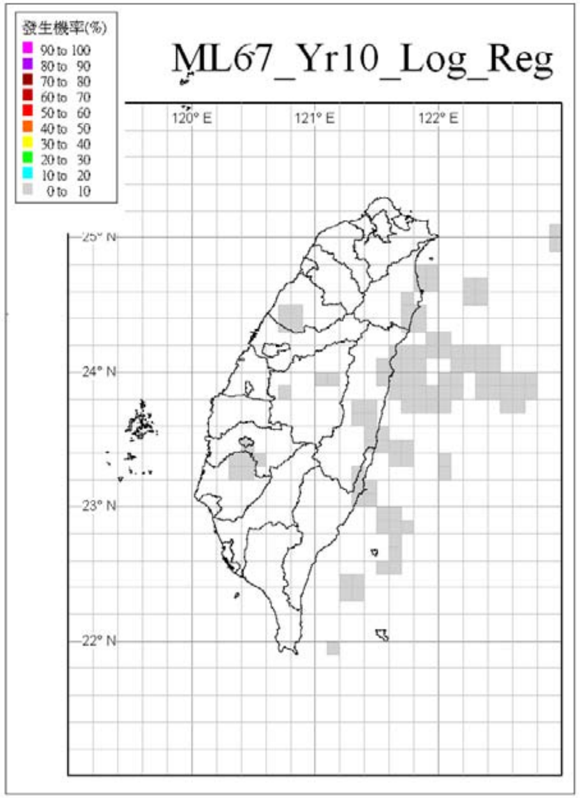


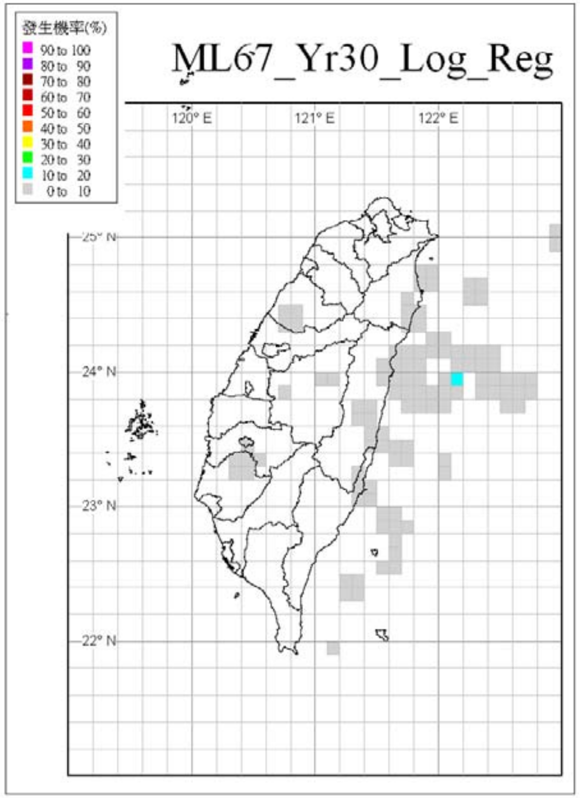


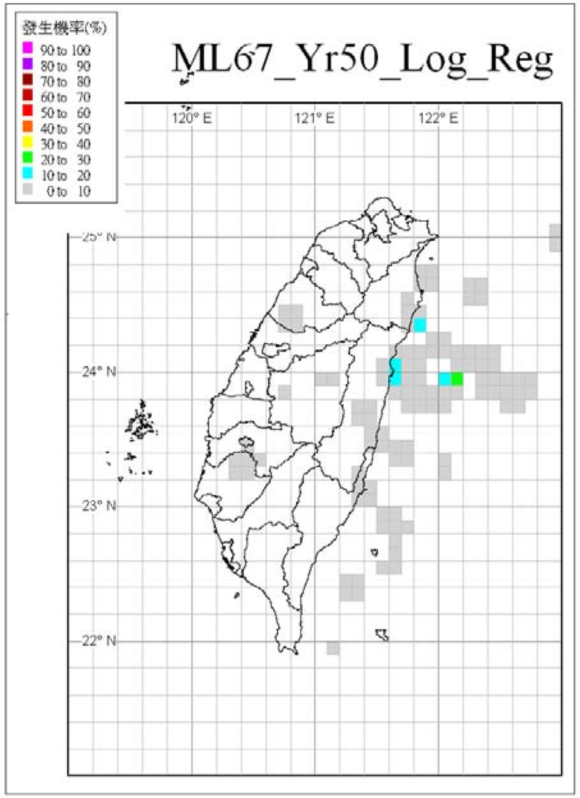


lognormal

Probabilities(%) for $M_L \geq 6.7$ in next 10, 30, 50 years

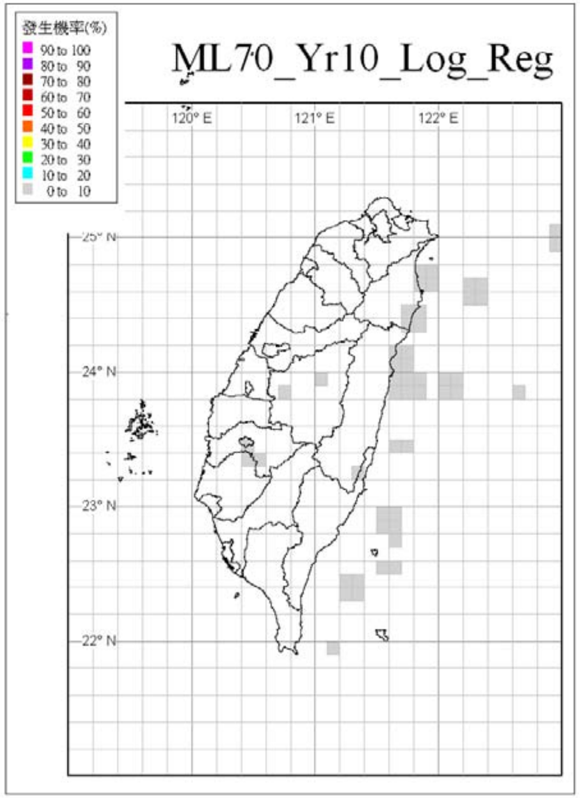


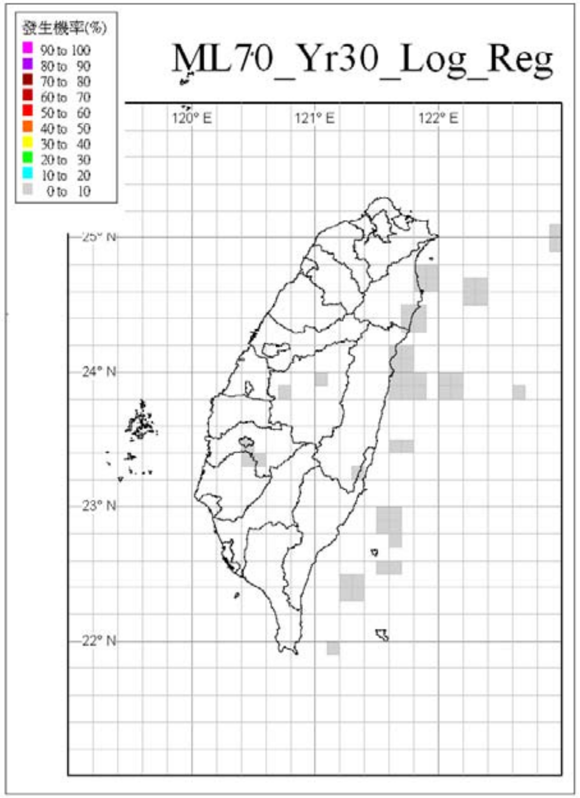


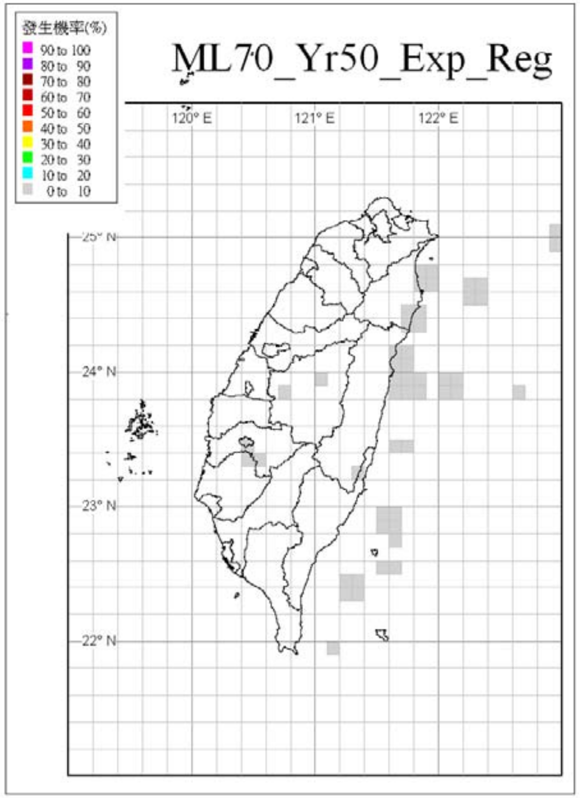


lognormal

Probabilities(%) for $M_L \geq 7.0$ in next 10, 30, 50 years







lognormal

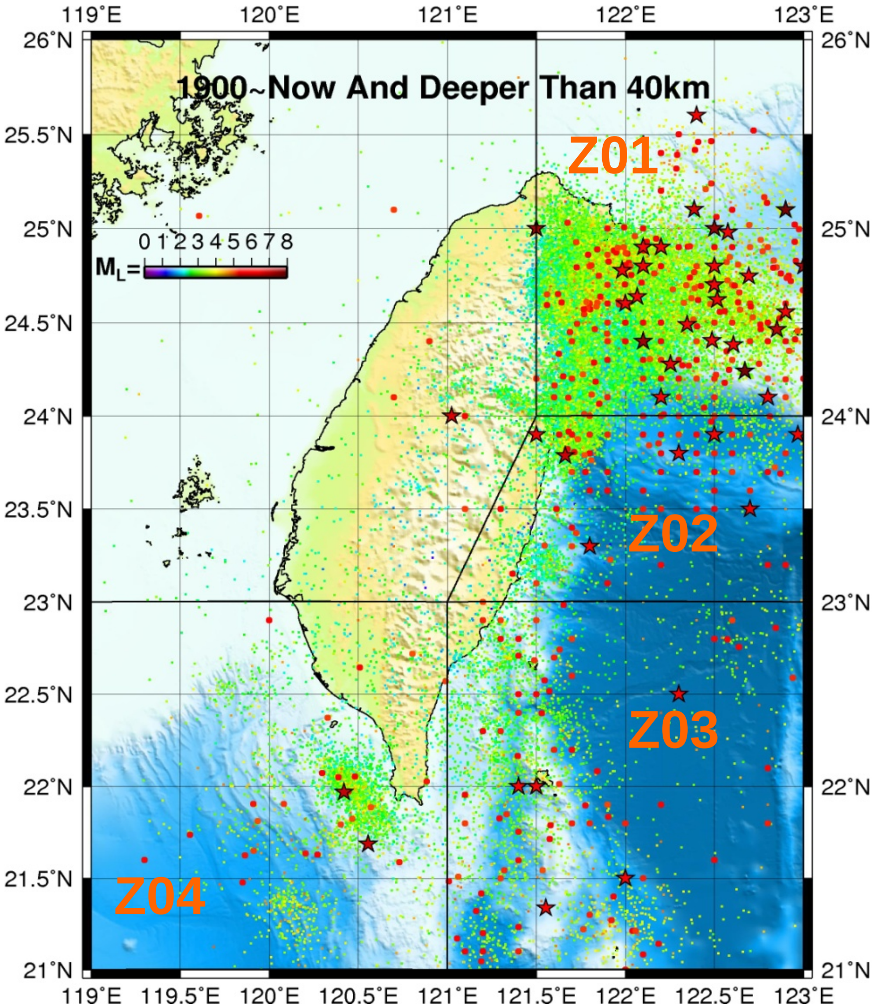
The color of each mesh look same due the interval is 10%, but numerical of each mesh is different.

Outline

- **Probabilities of the Potential Earthquakes - Regional Source**
  - **Deep zone: 4 zones**

Max. Earthquake: Cumulative Energy Method

(Maxropoulos and Burton, 1983)



Catalog: 1900-2010/12

Magnitude: $M_L \geq 4$

Depth: D >35 km

	M,obs	M,cal
Taiwan	7.3	7.6
Z01	7.3	7.4
Z02	7.0	7.1
Z03	7.1	7.1
Z04	7.0	7.2

Frequency and Magnitude Relationship (G-R Law)

Gutenberg and Richter (1944)

ZONE	a value	b value
Taiwan	3.43	0.93
Z 01	3.22	0.93
Z 02	2.78	0.88
Z 03	2.67	0.77
Z 04	2.32	0.81

Least Square Method

(1) b value:

$M \geq 0$, 1973-2010/12

(2) a value:

$M \geq 4$, 1900-2010/12

Initial anchor point :

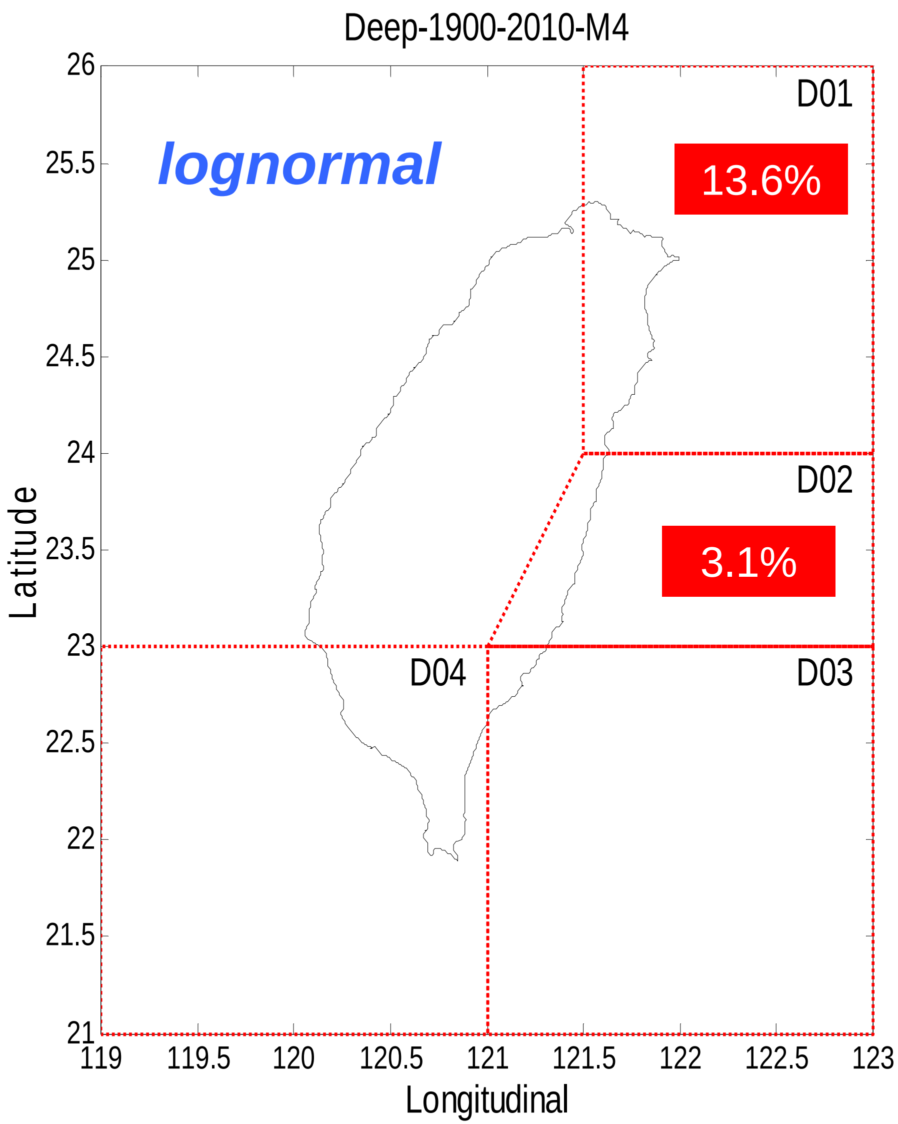
$M \geq 6$

Probabilities (%) for $M_L \geq 6$, $M_L \geq 6.7$, $M_L \geq 7$

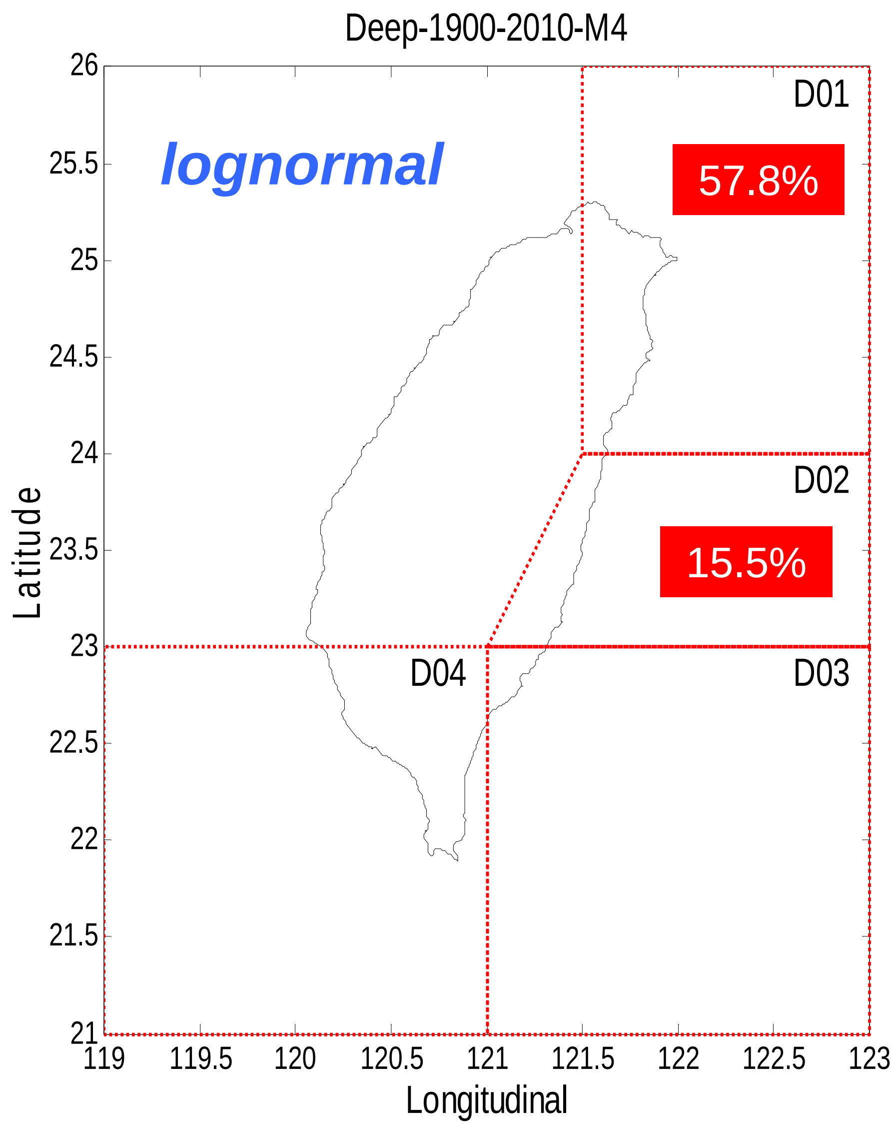
	M>6.0			M>6.7			M>7.0		
zone	10 year	30 year	50 year	10 year	30 year	50 year	10 year	30 year	50 year
Taiwan	96.0	99.8	100.0	63.3	91.3	96.8	38.0	72.5	85.5
D01	83.5	97.8	99.4	37.4	72.0	85.2	13.6	40.2	57.8
D02	69.6	93.6	97.8	10.0	39.0	57.9	3.1	9.4	15.5
D03	77.1	98.0	99.7	25.9	60.9	79.3	0.3	1.8	4.9
D04	25.9	79.8	94.5	0.01	2.4	11.3	0.01	0.01	0.1

lognormal

Prob. of $M_L \geq 7$ in next 10 yr

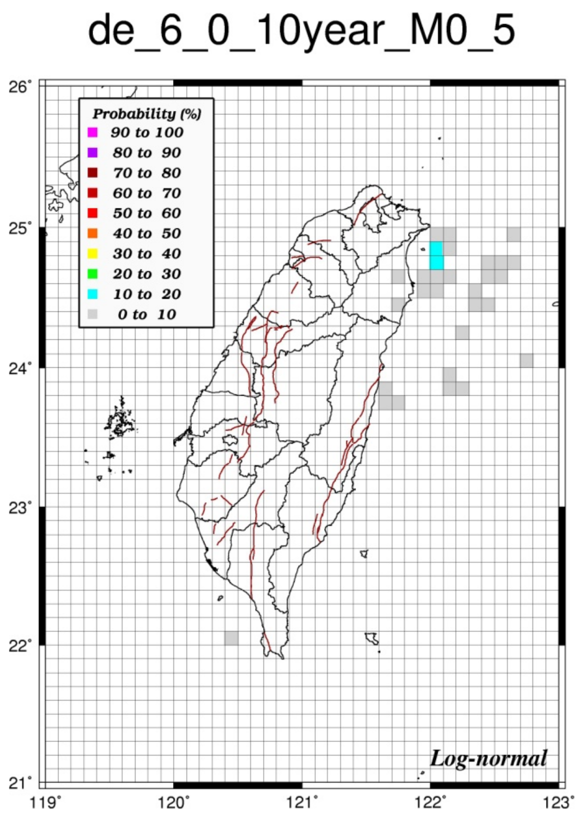


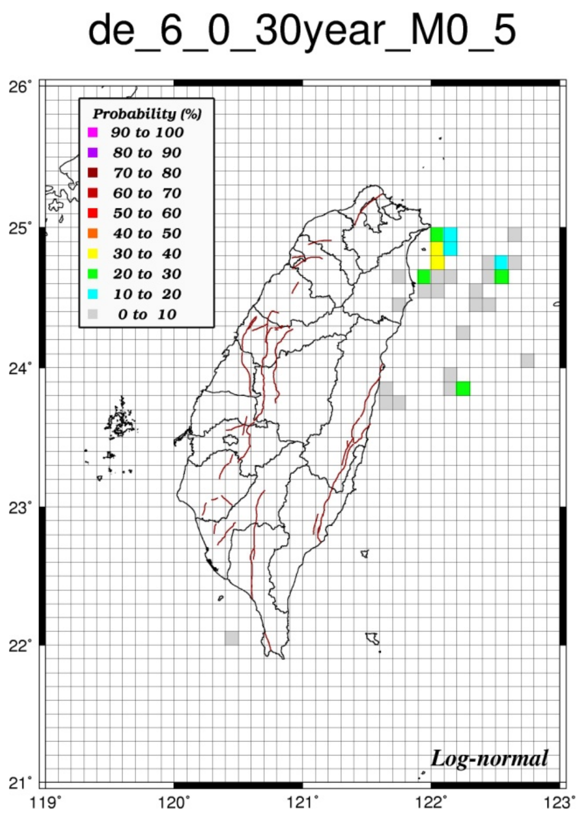
Prob. of $M_L \geq 7$ in next 50 yr

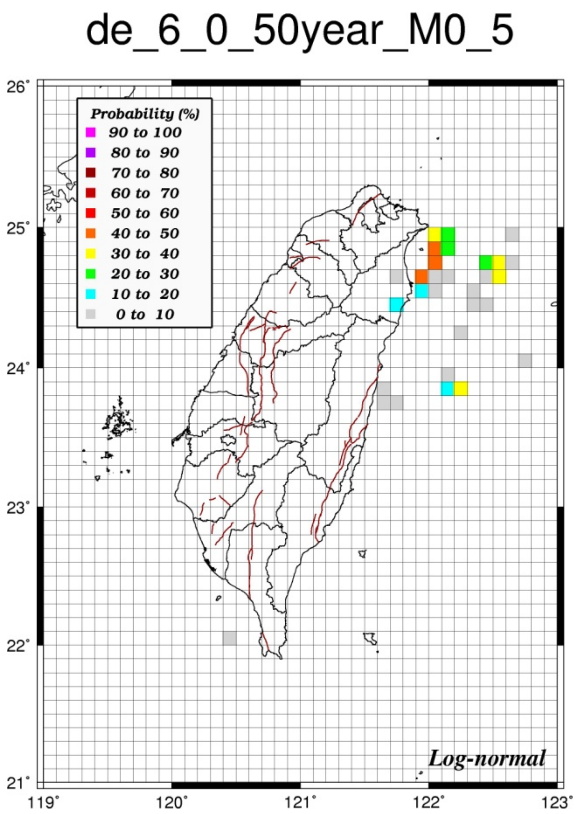


Recurrence Probabilities Utilizing Micro-zoning Method

Probabilities(%) for $M_L \geq 6$ in next 10, 30, 50 years



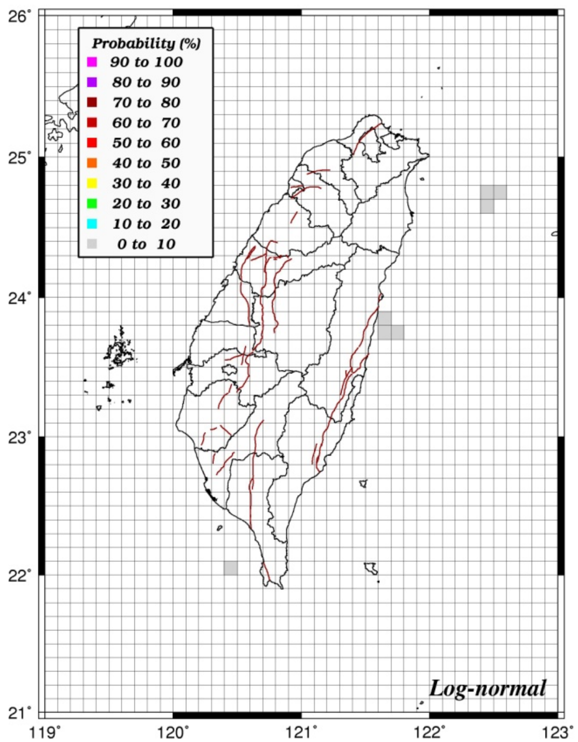




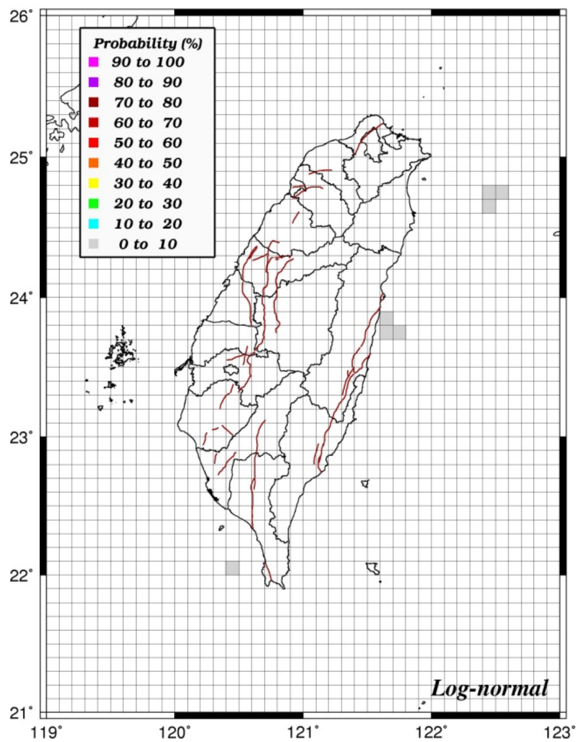
lognormal

Probabilities(%) for $M_L \geq 6.7$ in next 10, 30, 50 years

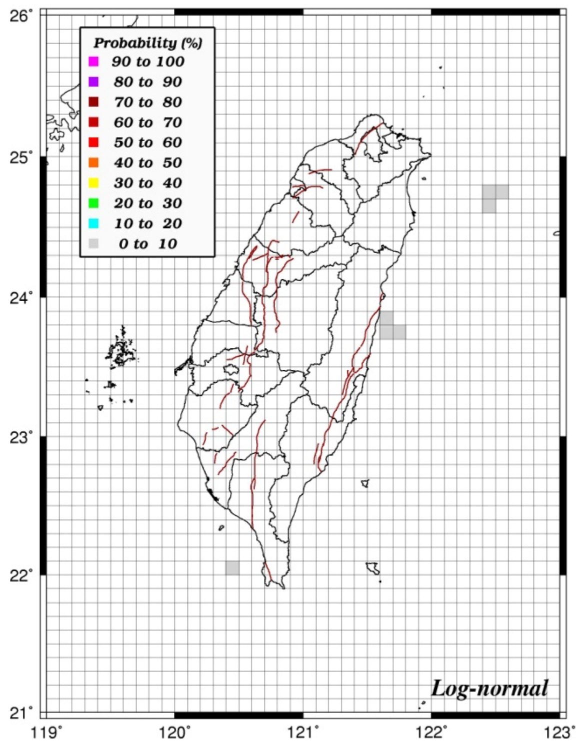
de_6_7_10year_M0_5



de_6_7_30year_M0_5



de_6_7_50year_M0_5

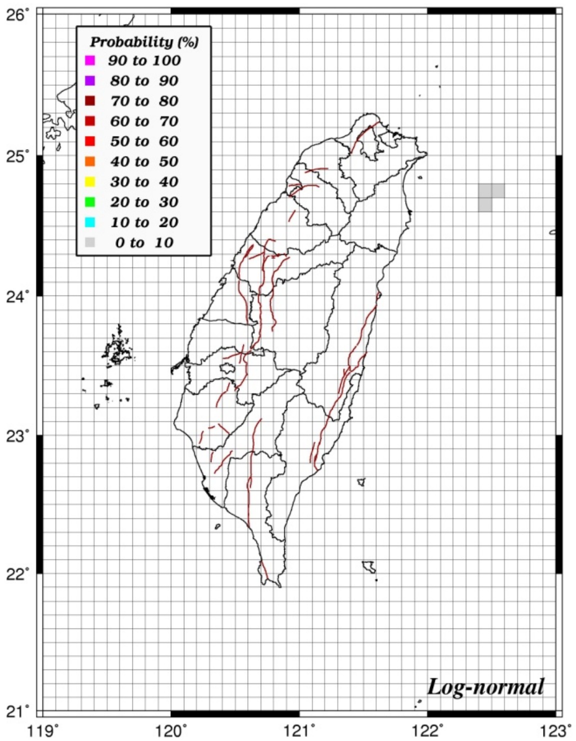


lognormal

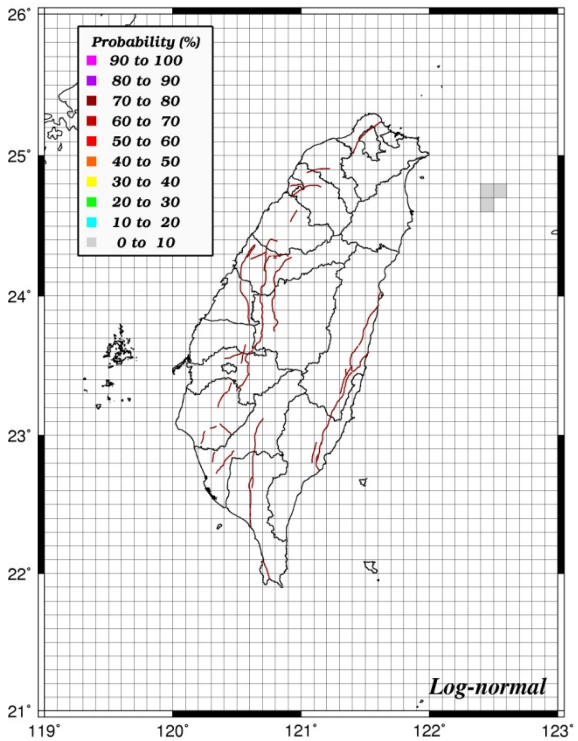
The color of each mesh look same due the interval is 10%, but numerical of each mesh is different.

Probabilities(%) for $M_L \geq 7.0$ in next 10, 30, 50 years

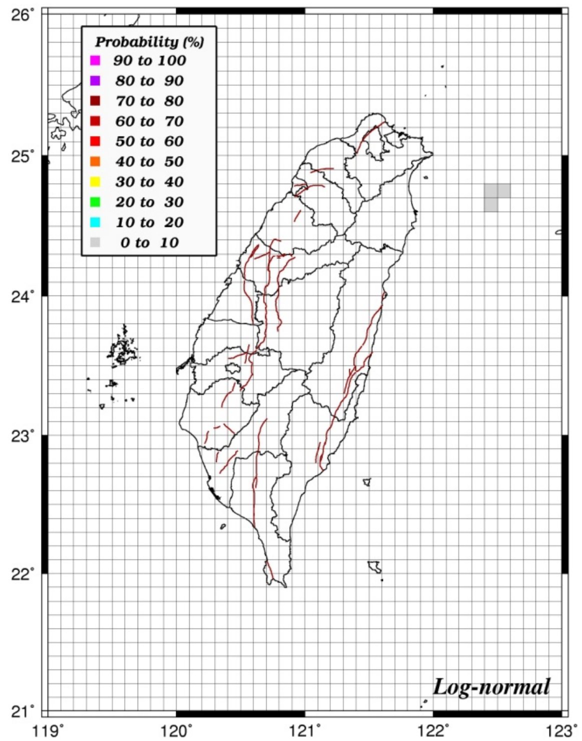
de_7_0_10year_M0_5



de_7_0_30year_M0_5



de_7_0_50year_M0_5



lognormal

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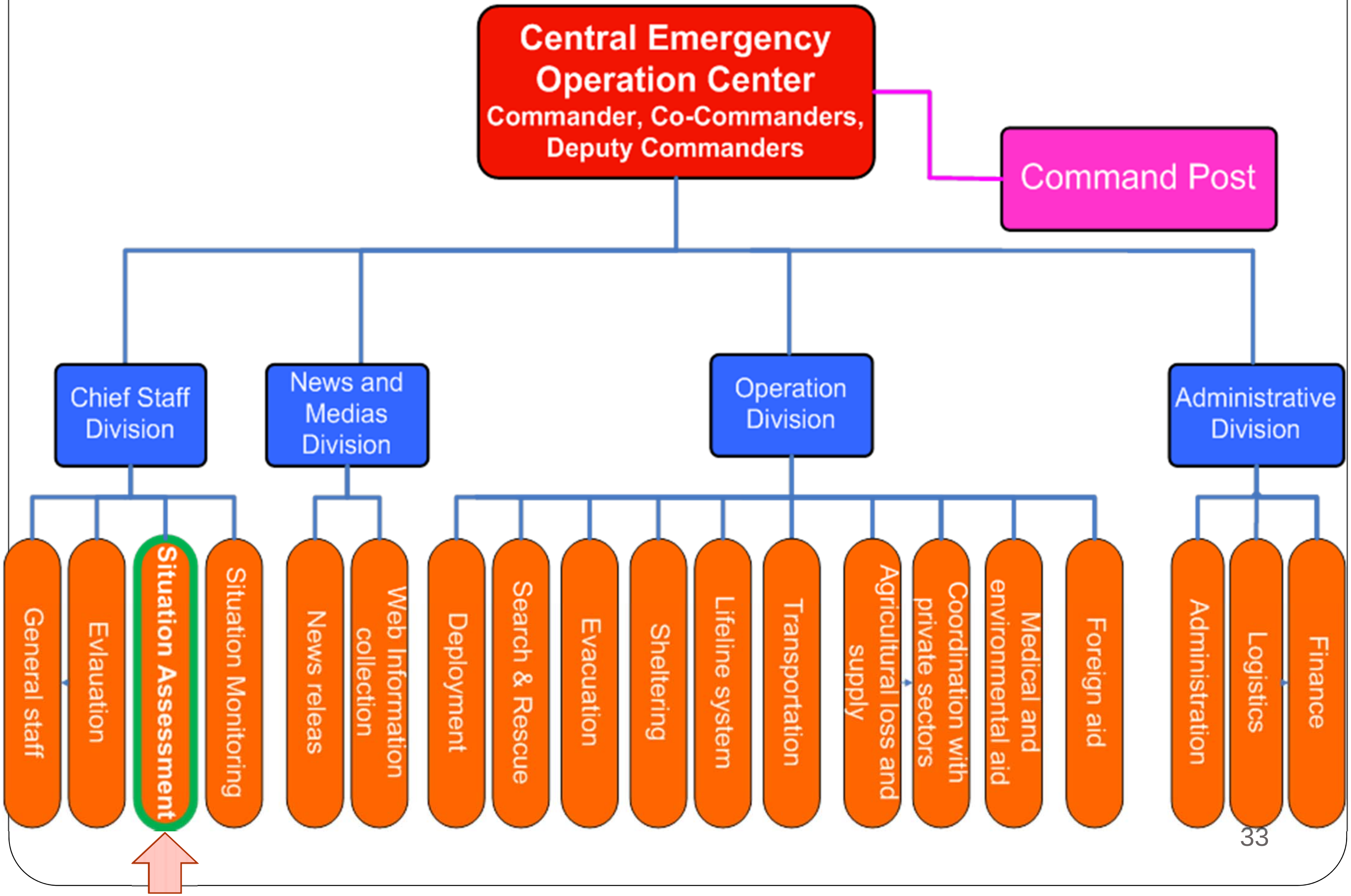
Outline

- **Operation of Emergency Response**
  - **Support Central Emergency Operation Center (CEOC)**

Current Structural Chart of CEOC



NCDR's Role in Emergency Response

NCDR runs scientific analysis

NCDR

- Internal Meeting every 3hrs
- Provide Analysis

1. Rainfall estimation
2. Flood potential
3. Debris flow potential
4. Precaution notice

Technology

NCDR summons the meeting

CEOC

- Assessment Meeting every 3hrs
- Generate Suggestions

1. Warning zones
2. Evacuation
3. Reinforcement
4. Bulletin to local government

Policy

NCDR reports to commander

CEOC

- Working Meeting
- Overall Review

1. Situation reports
2. Readiness report
3. Assistance and deployment
4. Emergency response

Implementation

Earthquake Disaster Response Framework

Response

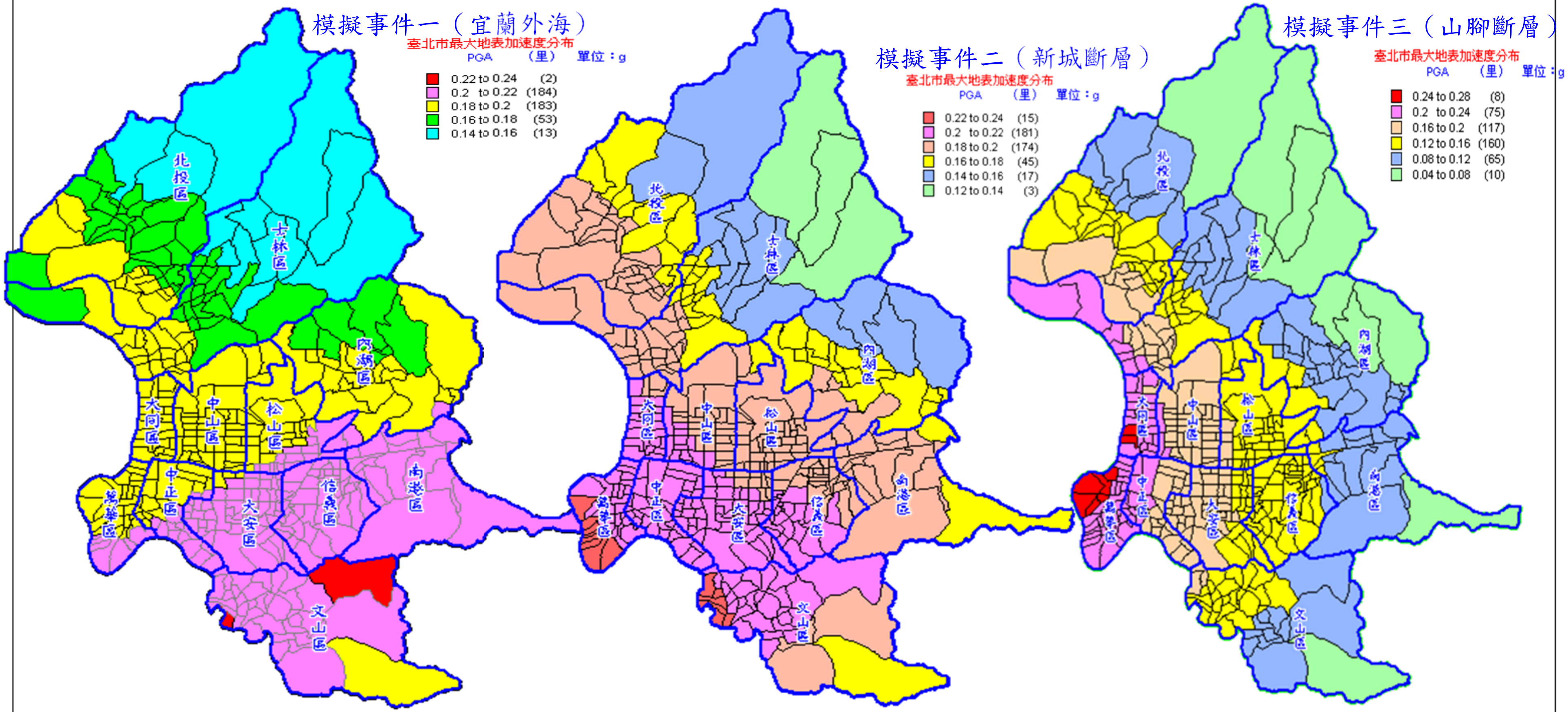
- **SOP**
- **Division of labor**
- **Information decision system**

NCDR provide suggestions of decision making for the commander with

- **the earthquake report by the Central Weather Bureau (CWB) and**
- **the estimation of possible disaster information, including exposure in areas with strong intensity and casualties and building collapse by Taiwan Earthquake Loss Estimation System (TELES) of National Center for Research on Earthquake Engineering (NCREE).**

Loss Assessment of Earthquake

Taiwan Earthquake Loss Estimation System, TELES



Developed by National Center for Research on Earthquake Engineering

SOP for Emergency Response in NCDR

Earthquake Report → Seismic Intensity → Evaluation → Disseminating

Report released by CWB：
Location
Focal depth
Observation

Intensity distribution
- Real-time observation

Prediction intensity
- Attenuation equation of ground motion

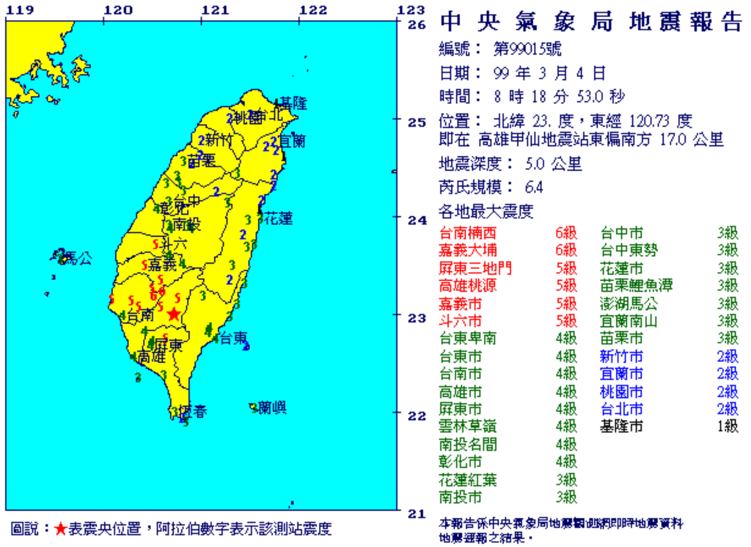
Traffic
- Roads
- Railway
- Bridge

Facilities
- Airport
- Power Plant
- Reservoir
- Industry Park

Schools
Hospital
Loss Estimation

Disseminating

Decision Support System for Emergency Response



中 央 氣 象 局 地 震 報 告

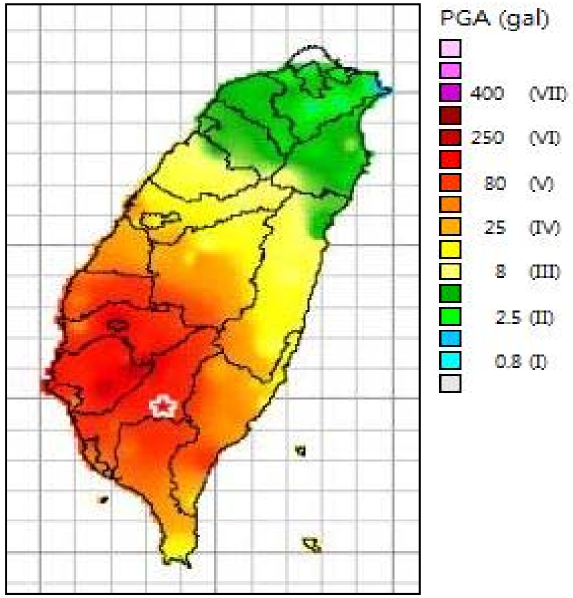
編號： 第99015號
日期： 99 年 3 月 4 日
時間： 8 時 18 分 53.0 秒
位置： 北緯 23. 度，東經 120.73 度
即在 高雄甲仙地震站東偏南方 17.0 公里
地震深度： 5.0 公里
芮氏規模： 6.4
各地最大震度

台南楠西	6級	台中市	3級
嘉義大埔	6級	台中東勢	3級
屏東三地門	5級	花蓮市	3級
高雄桃源	5級	苗栗鯉魚潭	3級
嘉義市	5級	澎湖馬公	3級
斗六市	5級	宜蘭南山	3級
台東卑南	4級	苗栗市	3級
台東市	4級	新竹市	2級
台南市	4級	宜蘭市	2級
高雄市	4級	桃園市	2級
屏東市	4級	台北市	2級
雲林草嶺	4級	基隆市	1級
南投名間	4級		
彰化市	4級		
花蓮紅葉	3級		
南投市	3級		

圖說：★表震央位置，阿拉伯數字表示該測站震度

本報告係中央氣象局地震觀測網即時地震資料地震速報之結果。

Contouring the intensity map according the announcement of CWB observation



Intensity distribution
- Real-time observation

Interpolation of the observation based on the method of inverse distance weighting to produce the intensity map.

Prediction intensity
- Attenuation equation of ground motion

Stage 1. (Chien, 2001)

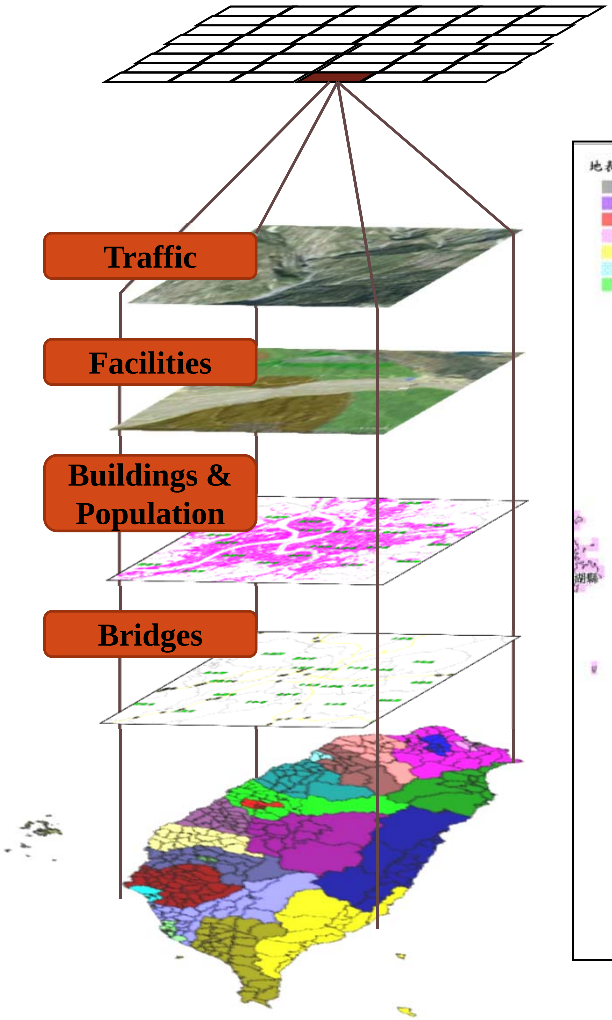
$$PGA_0(g) = 0.00369e^{1.75377M}\left[R + 0.1222e^{0.78315M}\right]^{-2.05644}$$

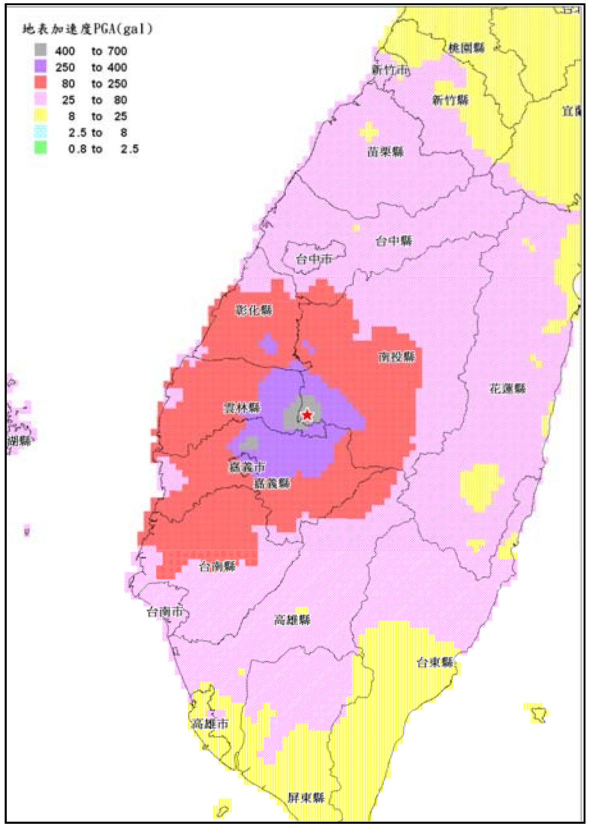
Stage 2. (詹皓凱, 2008)

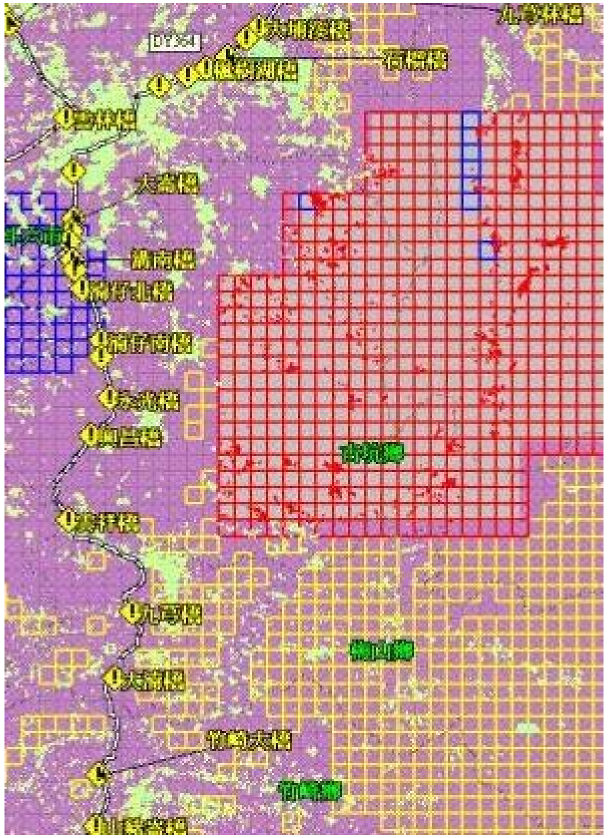
$$\ln(PGA_1)_i = C_0 + C_1 \times \ln(PGA_0)_i$$

Scenario-based output from analytic layers

Exposure + **Ground Motion** = **Areas with high risk**



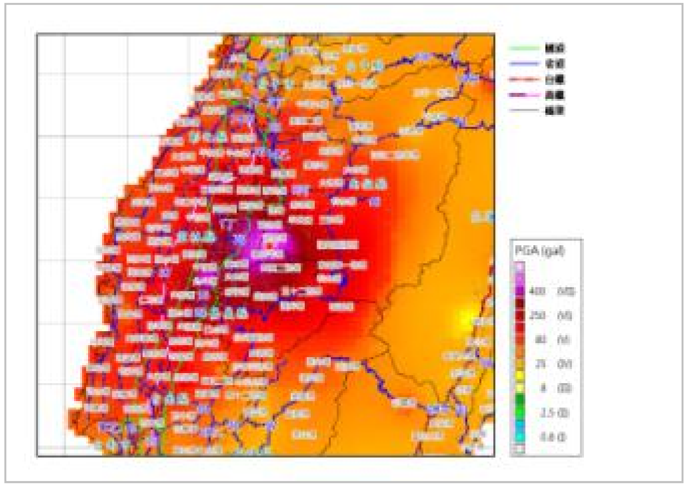




Analytic results are produced immediately and automatically after receiving the CWB report.

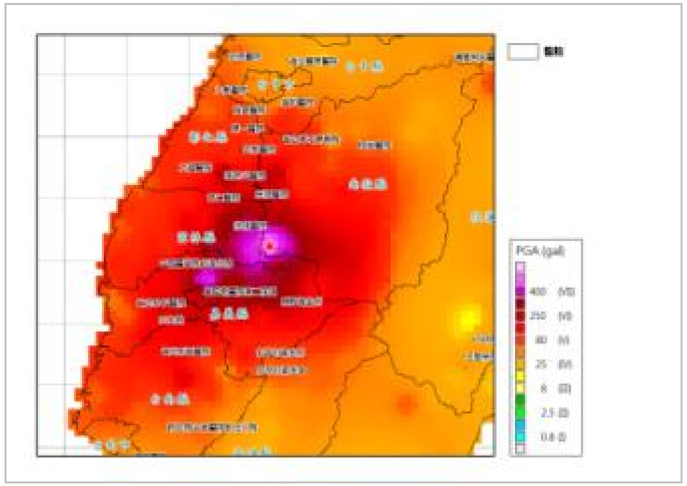
0-1hr即時產製圖資

- 強震區推估
- 強震區內交通設施（國道、臺鐵、高鐵、省道）提醒
- 強震區內重要設施（機場、電廠、水庫、工業區）提醒
- 強震區內學校安全評估
- 強震區內地區級以上醫院機能運作提醒
- 強震區內重要橋樑、重點橋樑提醒



位於六級震度(烈震)之橋梁：
1. 和平一號橋
2. 和平二號橋
3. 潘子溝橋
4. 宮聖橋
5. 進興橋

位於七級震度(劇震)之橋梁：
1 雙福橋
2.廓底橋
3. 湖尾橋
4. 民雄排水橋



位於六級震度(烈震)之醫院：
1. 成功醫院
2. 彌勒醫院
3. 佛教慈濟大林醫院
4. 聖馬爾定醫院
5. 基督教醫院
6. 嘉義醫院
7. 榮民醫院
8. 鎮源農民醫院
9. 張綜合醫院
10. 卓綜合醫院
11. 雲林醫院
12. 國軍斗六醫院
13. 灣橋榮民醫院

位於七級震度(劇震)之醫院：
(無)

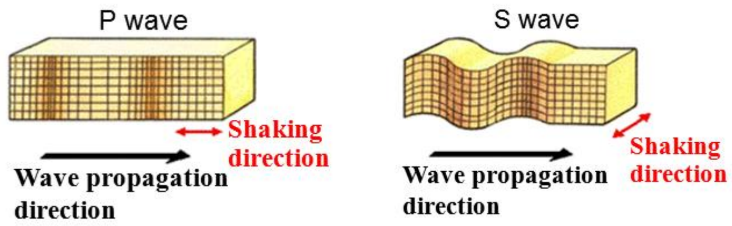
Output of GIS-based layer and disseminating the evaluations via E-mail and SMS of cellphone.

Outline

- **Promotion of Earthquake Early Warning**

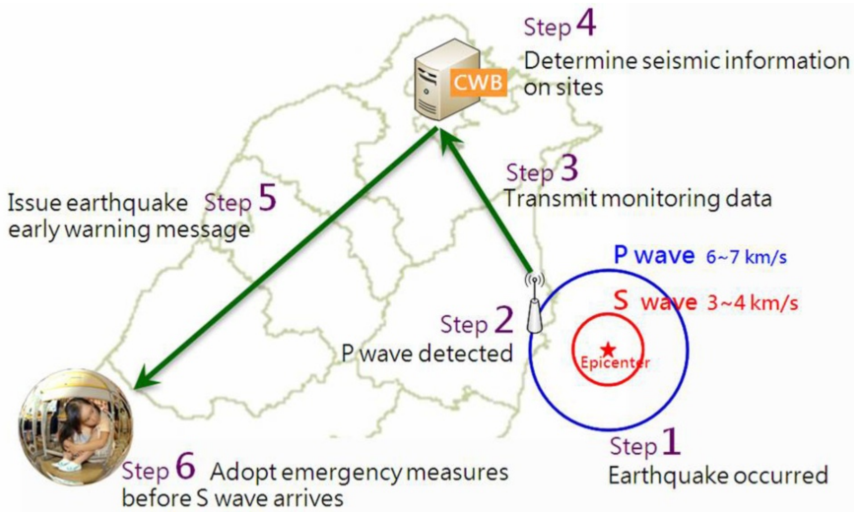
Promotion of Earthquake Early Warning System

Introduction of Earthquake Early Warning System (EEWs)



Regional EEWs

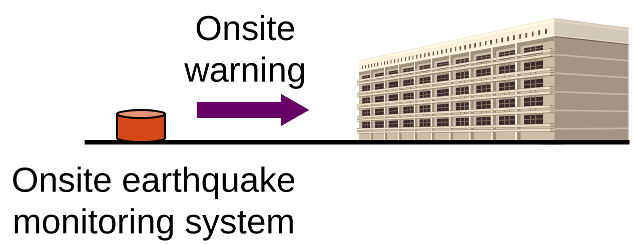
- Use real-time monitoring network to determine earthquake location and send warning message to distant regions away from epicenter before S waves arrive.
- So far, regional warning in Taiwan is available for regions with epicentral distance greater than 60 km.



Regional EEW system

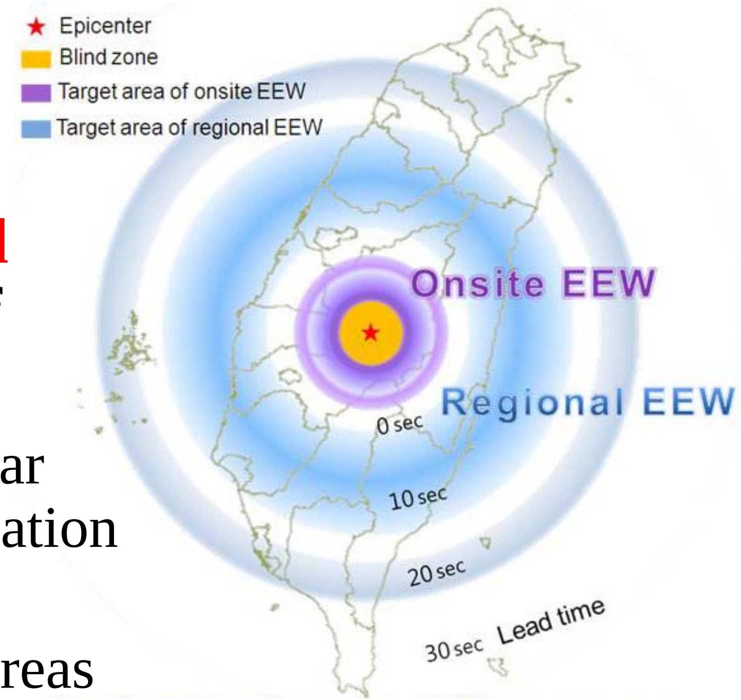
Onsite EEWs

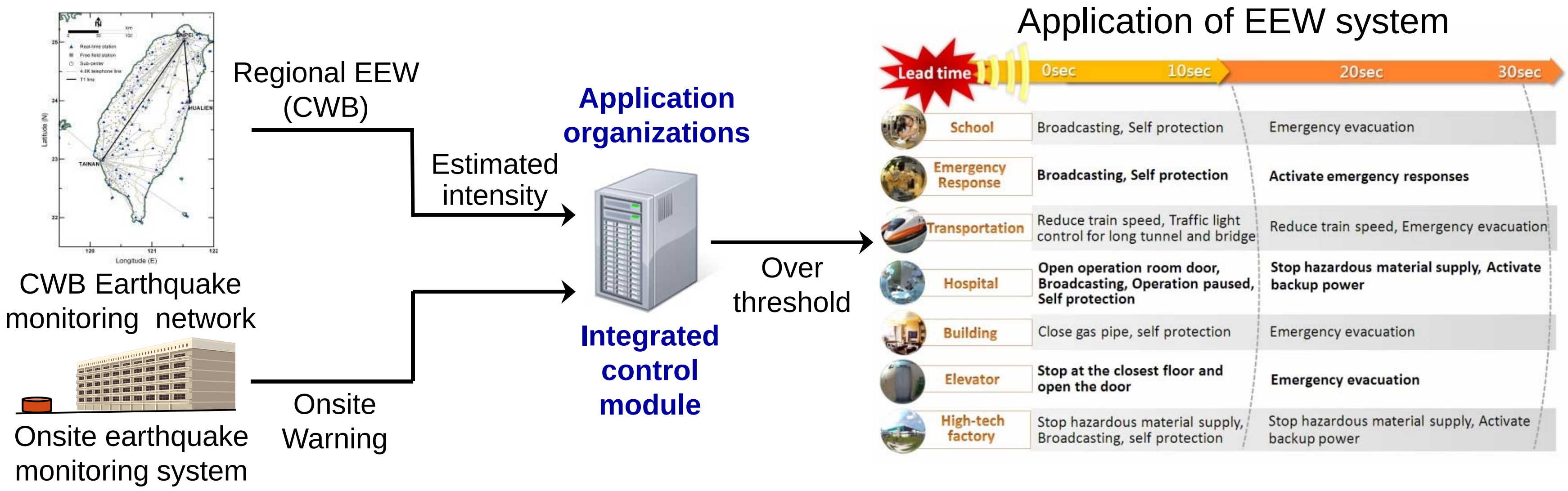
- Seismographs are implemented in-situ to detect P waves and provide onsite warnings.
- Onsite warnings may be available to the areas within the epicentral distance ranging from 30 to 60 km.



Challenges and solutions of promoting EEWs in Taiwan

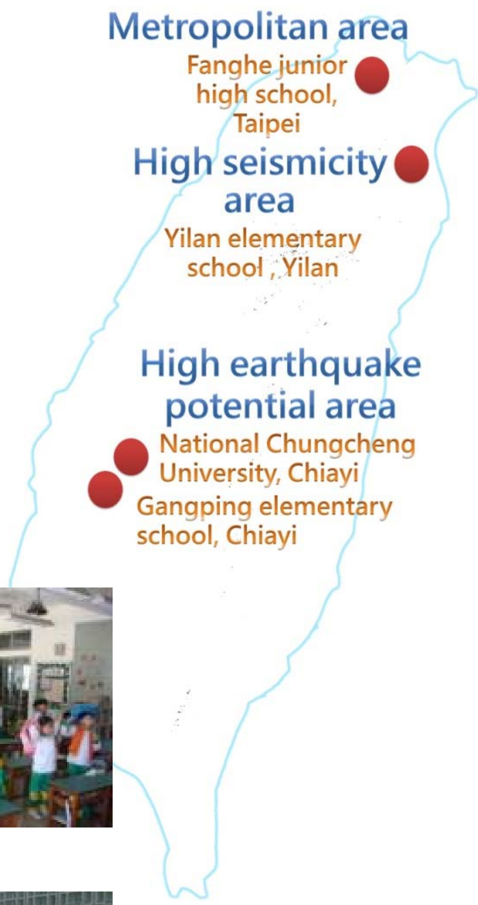
- **It is necessary to integrate the regional and onsite warning systems because of the small land of Taiwan.**
  - People can receive the regional warning far away the epicenter via various communication channels.
  - The onsite technology can be applied to areas near the epicenter.

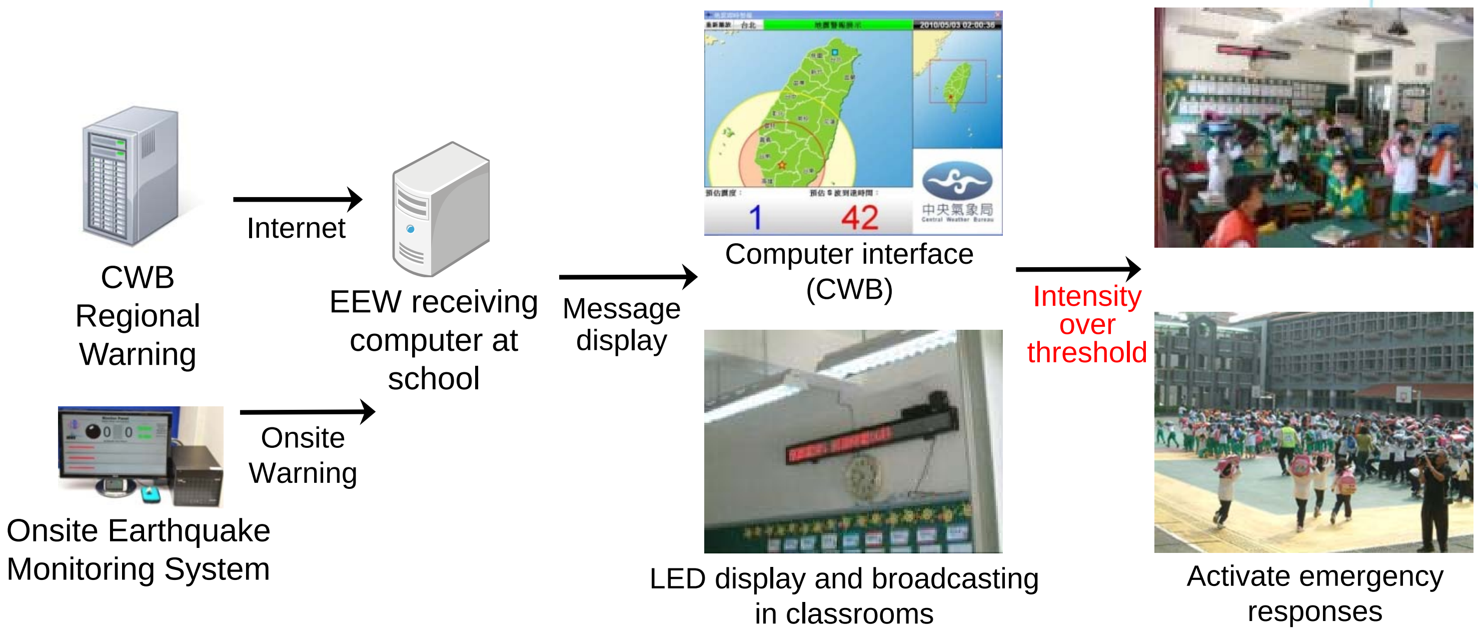




Application of EEWs to Schools

- Regional and onsite EEW message was linked with the broadcasting system to automatically inform teachers and students at 4 schools with collaboration of NCDR, CWB, and NCREE.

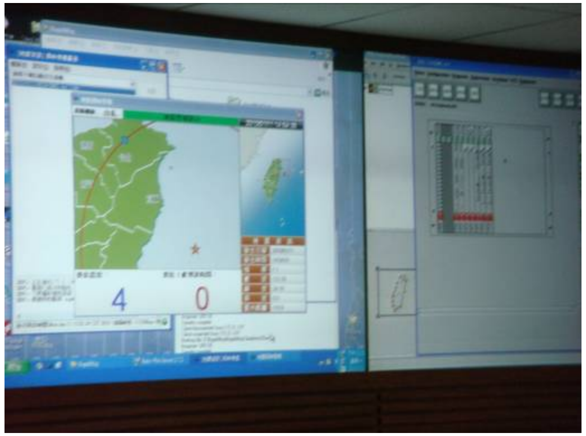




Promotion of Earthquake Early Warning System

Pilot test at Emergency Response Center

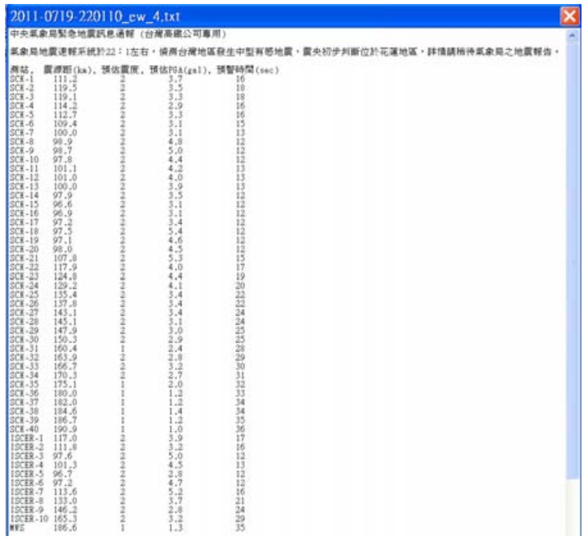
- EEW message was received via internet at National Fire Agency for testing with collaboration of NCDR, CWB, and NCHC.



EEW received via internet

Pilot application for Taiwan High Speed Rail

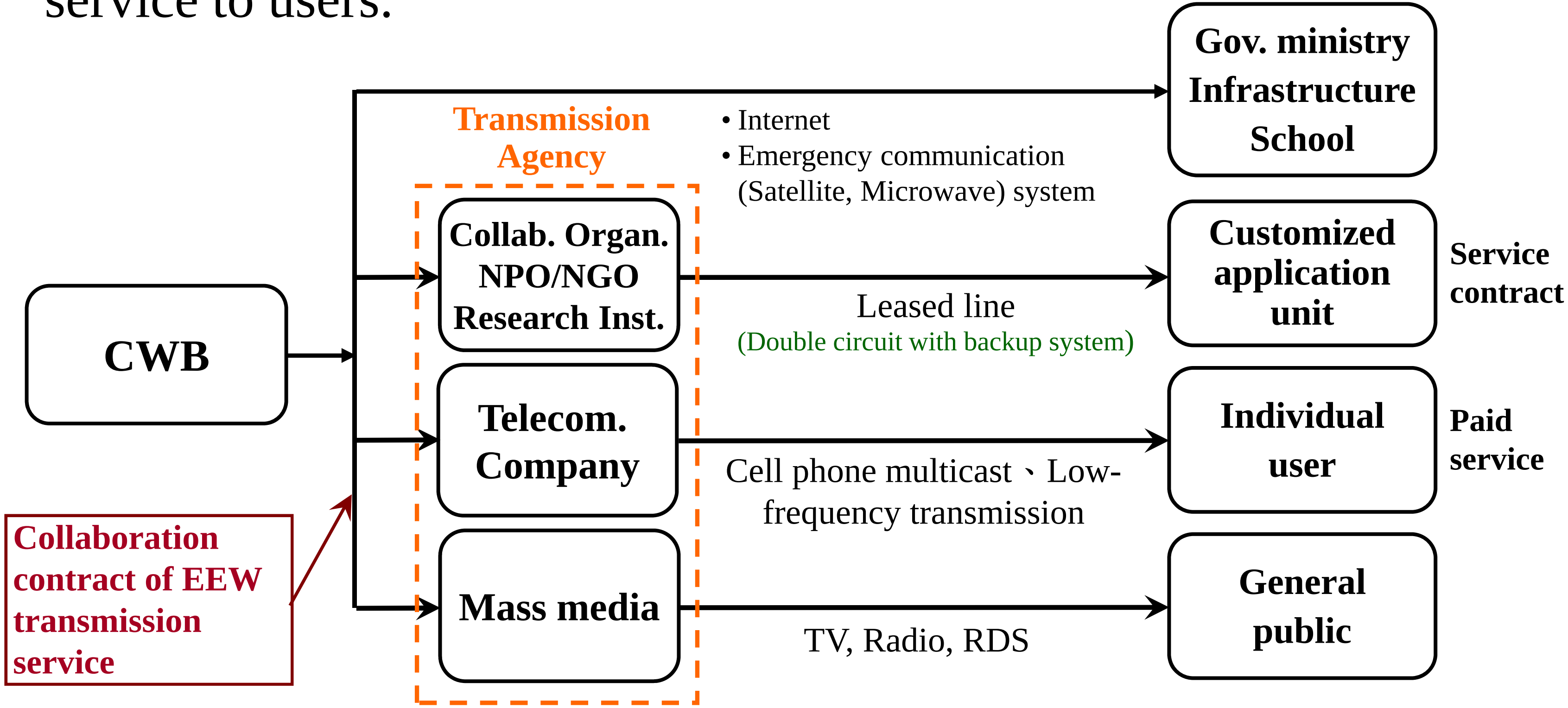
- Customized EEW message was sent by CWB to THSR for testing and pilot application with collaboration of CWB, NCDR, and NCREE.



EEW message for Taiwan High Speed Rail

Planning of EEW Transmission Mechanism

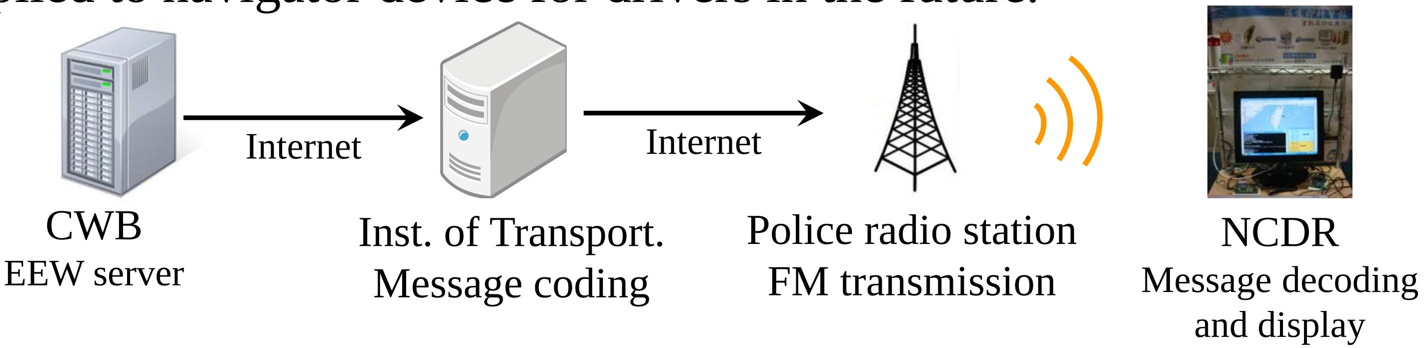
- Public sectors: CWB send EEW directly to government ministries, infrastructures, schools via internet and emergency communication system.
- Private sectors: By collaboration contract with CWB, transmission agencies are allowed to provide EEW transmission and customized service to users.



Promotion of Earthquake Early Warning System

nsmission test using the Radio Data System

The radio data system is used for EEW transmission test with collaboration of Inst. of Transportation, MOTC, CWB, NCHC, and NCDR. It may be applied to navigator device for drivers in the future.



nsmission test using Low-Frequency Time and Frequency adcasting System

The Low-Frequency Time and Frequency Broadcasting System is used for EEW transmission test with collaboration of Bureau of Standards, Metrology and Inspection, MOEA, Chunghwa Telecom Institute, CWB, and NCDR.

Ground Motion Prediction

kshop on Seismic Hazard Assessment Issues in
land arc of Taiwan and Japan
4-6th 2012, NCU, Taiwan

~Thanks for *Your* Attention~

wenkl@earth.ncu.edu.tw