交通部中央氣象局
地震測報中心

Seismological Center,
Central Weather Bureau

第六屆台日地震前後地下水異常變化研究國際研討會
6th Taiwan - Japan Workshop on Hydrological and Geochemical Research for Earthquake Prediction

Current Status and Development of Earthquake Observations in Taiwan

Nai-Chi Hsiao (蕭乃祺)
Seismological Center, Central Weather Bureau (CWB)
September 26, 2007

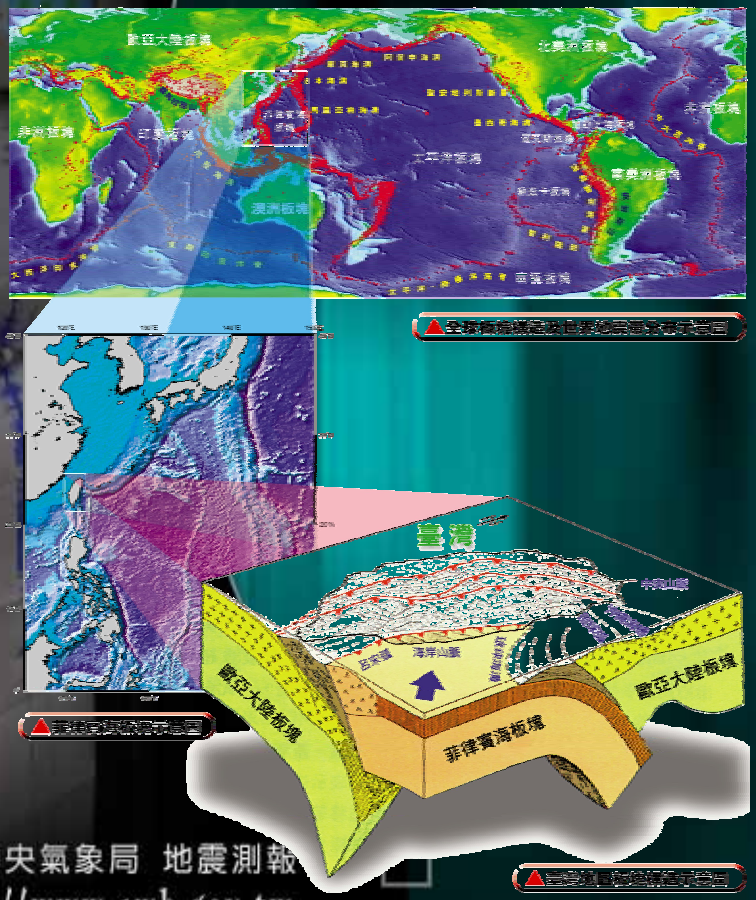
http://www.cwb.gov.tw

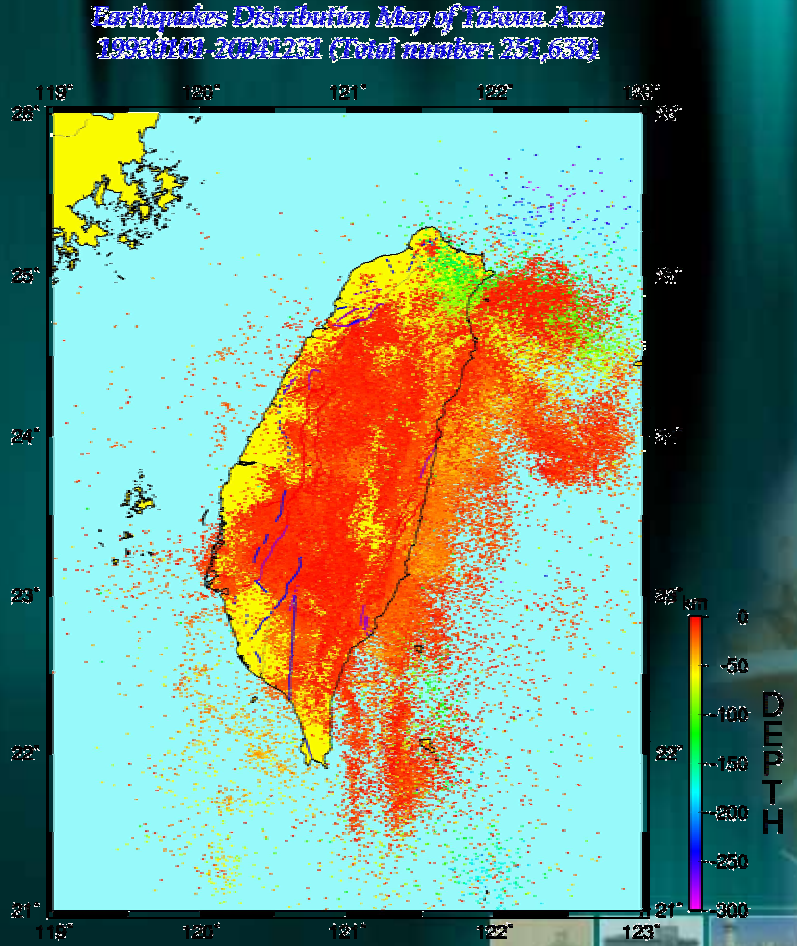
Outline

- Introduction
- Current status
- Future development
- Other earthquake related observational networks at CWB

Introduction

Taiwan, an island located on the border of the Eurasia plate and the Philippine Sea plate, is over the Circum-Pacific seismic belt.





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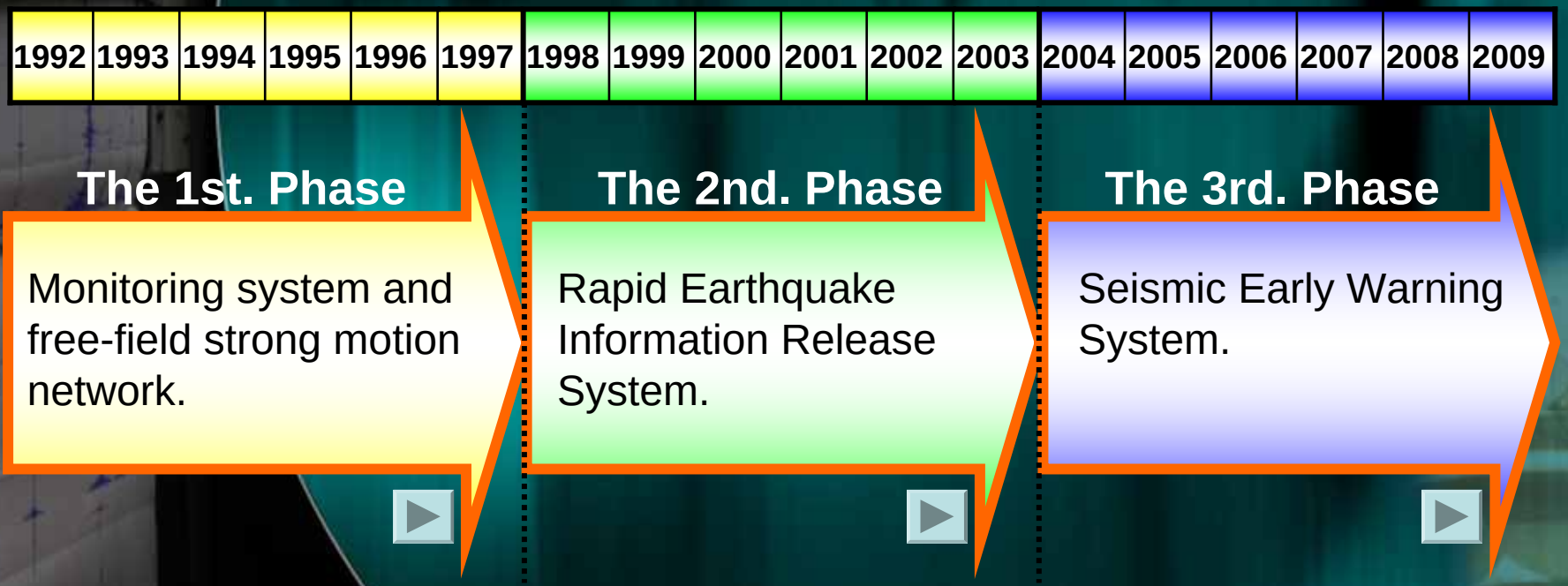
Introduction

There are nearly 18,000 seismic events occurring in and around Taiwan every year, and earthquake hazard is one of the major natural disasters in Taiwan. In order to monitor and report seismic activities for earthquake hazard mitigation, the Central Weather Bureau (CWB) has been executing projects of Taiwan Strong Motion Instrumentation Program (TSMIP) since 1992.

year / magnitude	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
7≦M	1	0	0	1	0	0	0	0	1	0
6≦M＜7	2	2	1	14	3	3	6	2	3	2
5≦M＜6	19	20	20	83	31	13	30	24	15	26
4≦M＜5	222	177	145	732	260	203	244	220	176	238
3≦M＜4	1890	1290	1329	5122	1822	1450	1984	1556	1406	1490
2≦M＜3	8750	7900	7647	26582	12803	7827	13298	11464	9196	9325
M＜2	6094	6261	5838	17385	9470	6748	12535	12183	10986	10980
TOTLE	16978	15650	14980	49919	24326	16244	28097	25499	21783	22061

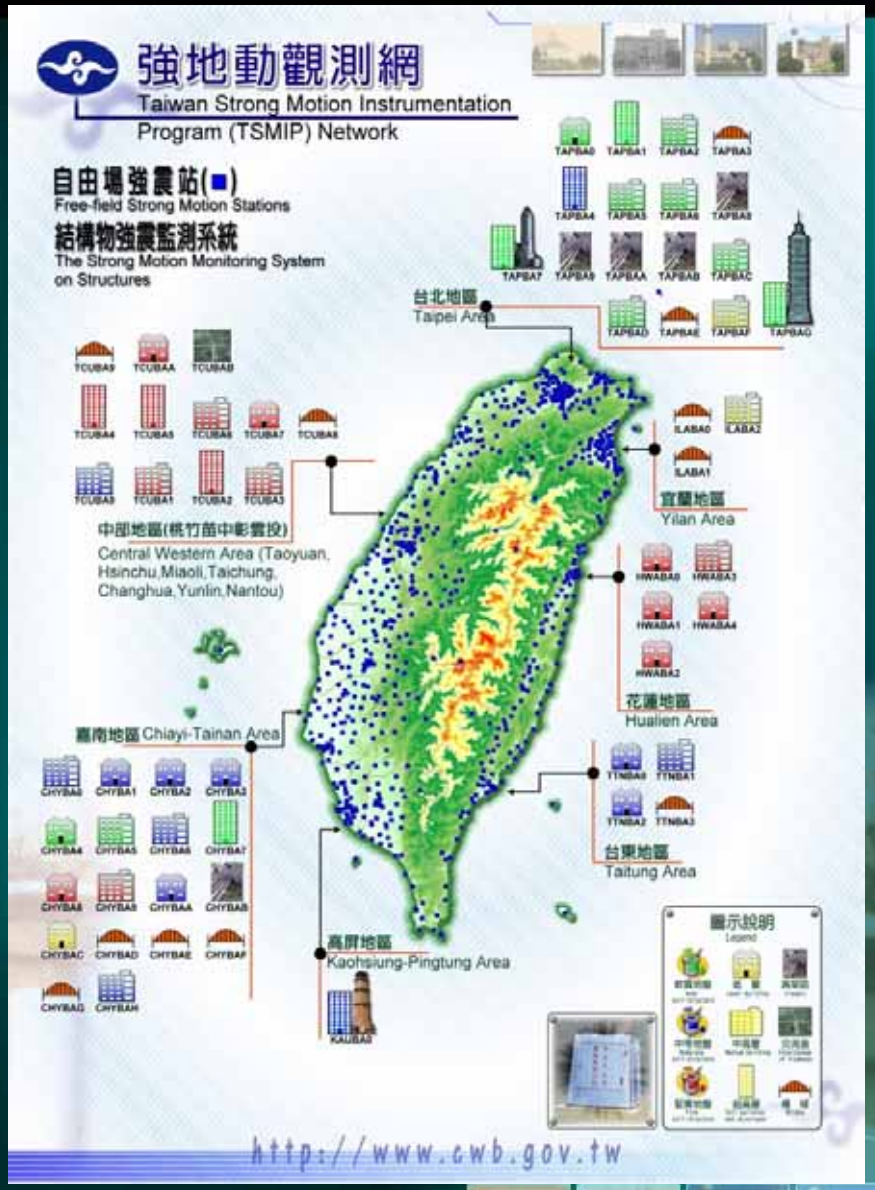
Introduction

The TSMIP is a comprehensive, forward-looking, and continuous push-on project, and divides into three phases for every six years.



Executing projects of Taiwan Strong Motion Instrumentation Program：

- The first phase of the project is building a monitoring system and a network in urban areas with free-field strong motion stations. This includes gathering strong motion data around Taiwan and providing them for institutions of engineering and disaster prevention, while revising building codes for earthquake resistant construction.



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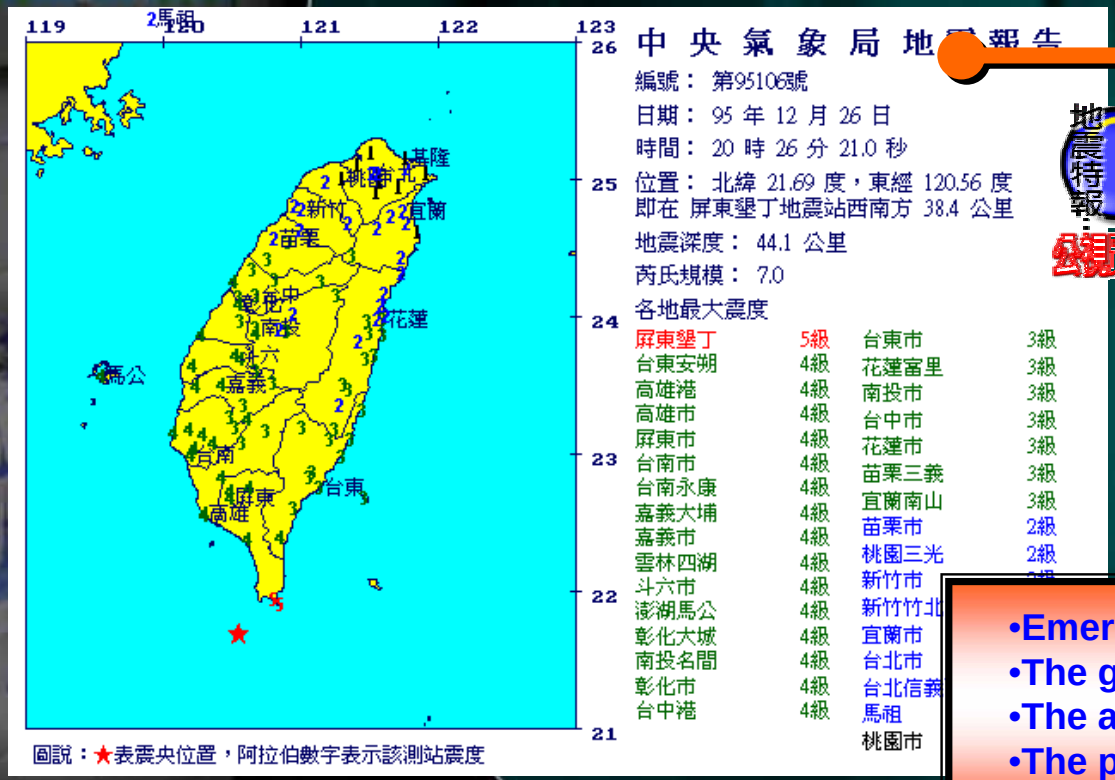
Executing projects of Taiwan Strong Motion Instrumentation Program：

- The second phase is mainly constructing an earthquake rapid reporting system (ERRS). The goal is to reduce the communication time for emergency response with related units.



- Emergency servies
- The general public
- The authorities
- The public media
- Transportation system
- Seismological institutes
- Engineering system
- Power(plants & grids)

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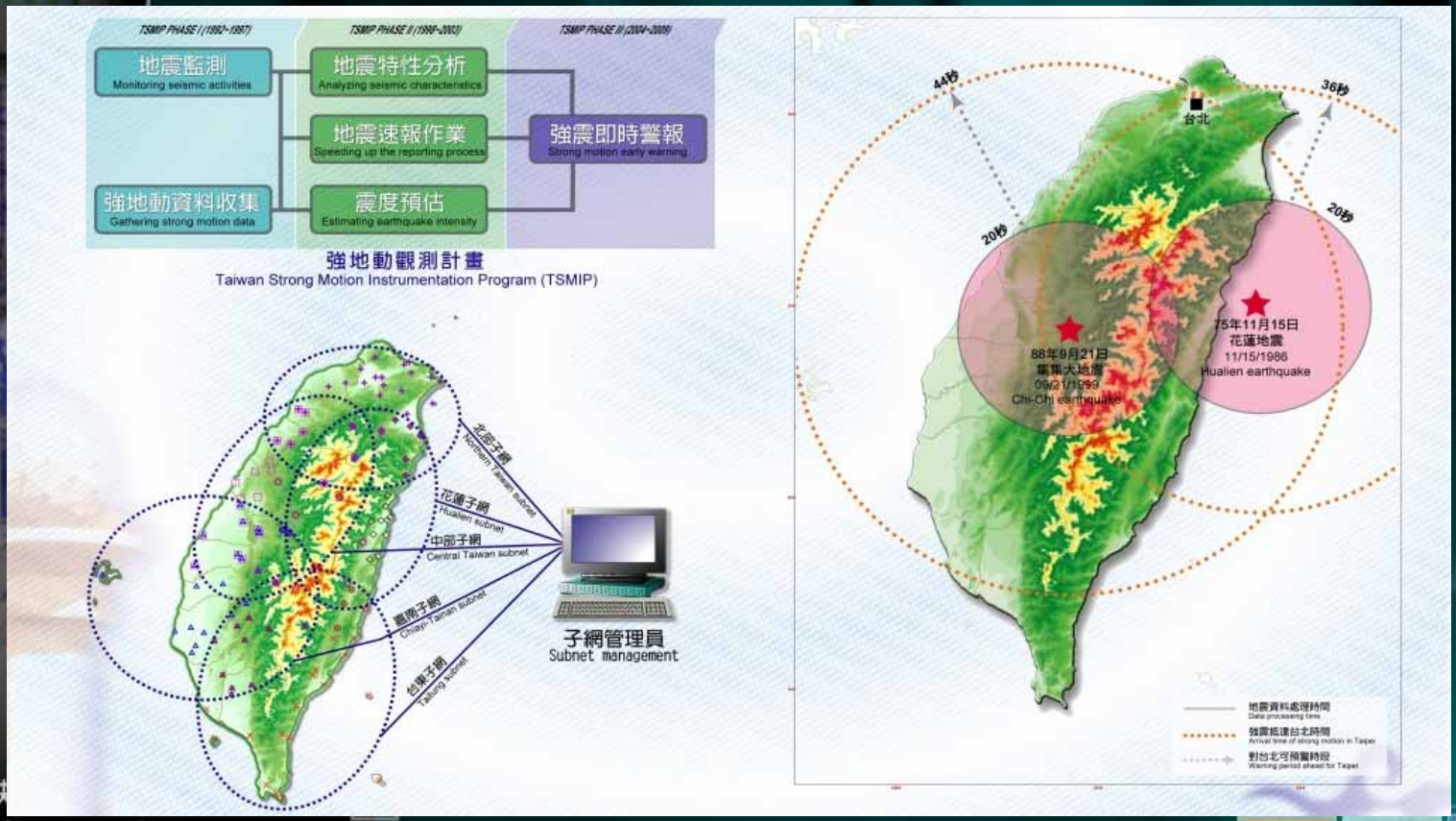
Executing projects of Taiwan Strong Motion Instrumentation Program：

- The third phase of the project focuses on the earthquake early warning system (EEWS). We emphasize research and development on the early warning system of seismic strong motions.

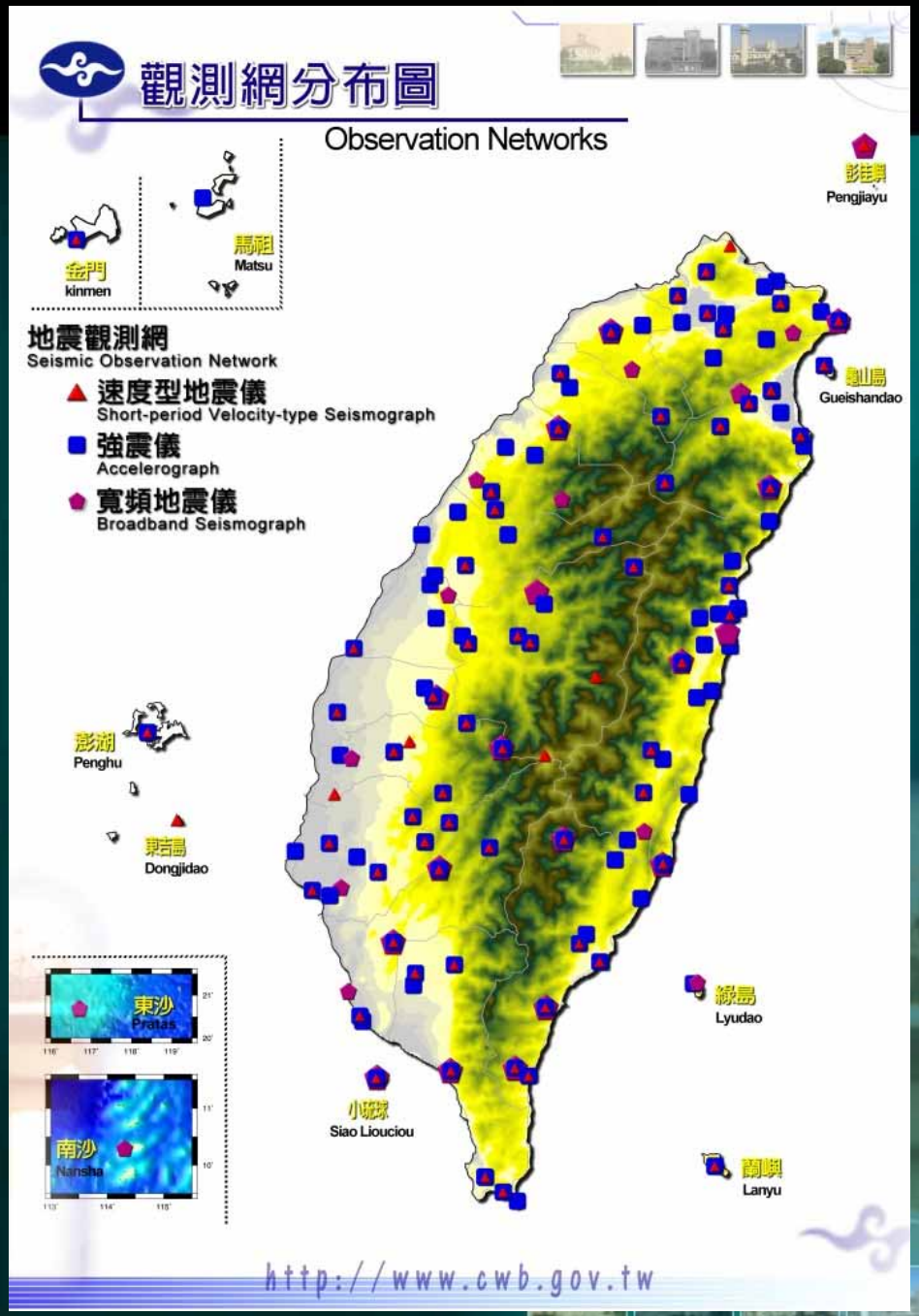


Current status

- CWBSN (Central Weather Bureau Seismographic Network)
  - Short period seismograph
  - Strong-motion seismograph (accelerograph)
  - Broadband seismograph
- TSMIP network
  - Free-field station
  - Building array

CWBSN

- Short-period seismograph -
  - GeoTech S13 sensor
  - 70 stations
  - 12 bits resolution
  - Seismicity observation
- Accelerograph -
  - GeoTech A900A
  - 101 stations
  - 16 bits resolution
  - ± 2G Max. amplitude
  - Hazard mitigation



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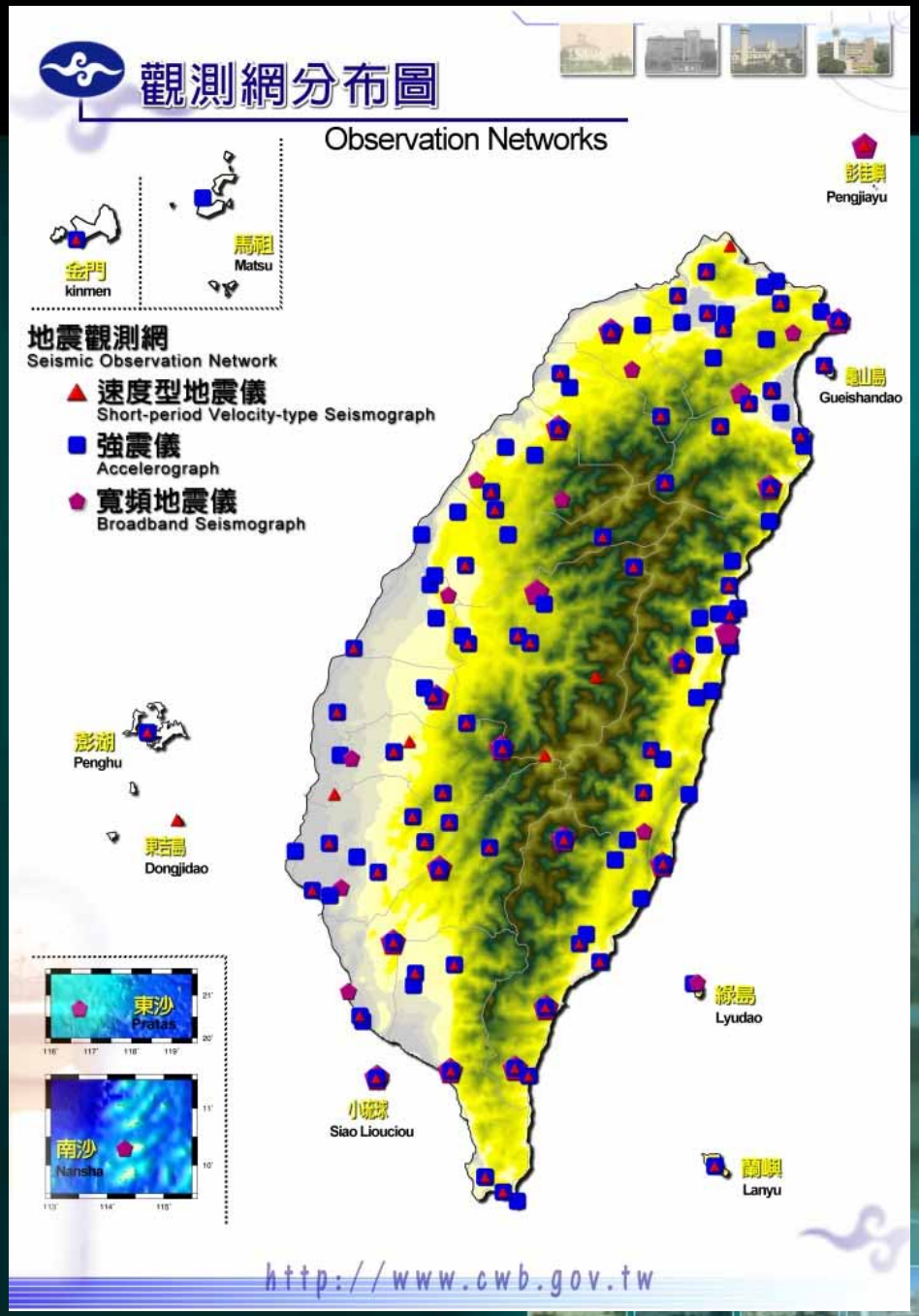
CWBSN

- Broadband seismograph -
  - Guralp 3ESP, 40TD sensor
  - 32 stations
  - 24 bits resolution
  - 0.02-30 sec period range
  - Focal mechanism, global earthquake observation



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Seismograph

Station Instrument A900A & S13

Broadband sensor

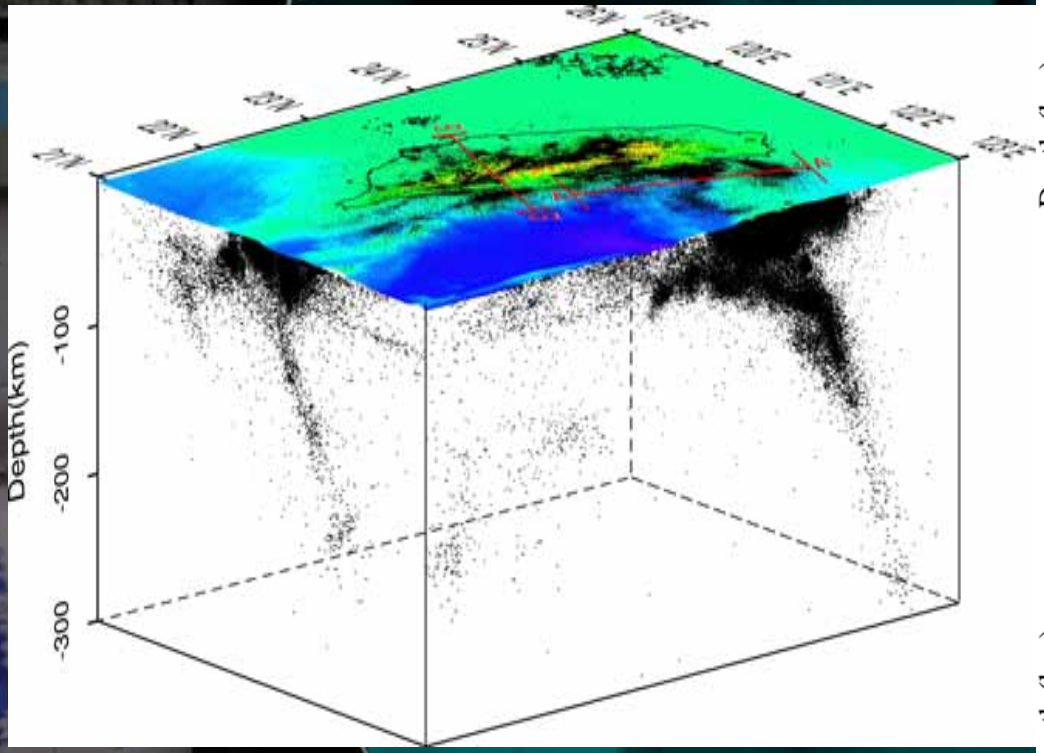
Data transmission & procession

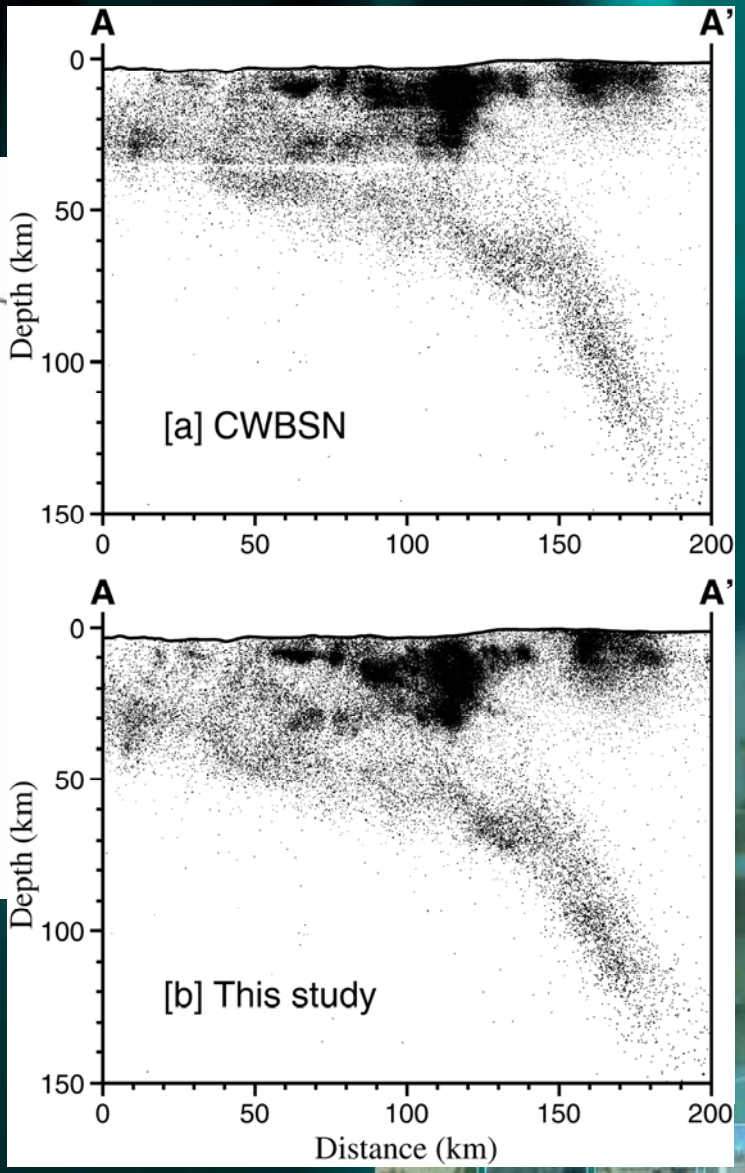
- Short-period and accelerograph
  - real-time data stream (RTD)
  - 4.8K bps telephone line
  - 50 sps (acc.), 100 sps (sp)
  - Windows-based workstation
  - Self-developed software
- Broadband
  - UDP packet switching
  - 64K frame-relay network and satellite link
  - 100 sps
  - Windows-based & Unix workstation
  - USGS Earthworm software

Achievements

- Seismicity observation
  - Taiwan earthquake database
- Taiwan Tectonic research
- Seismic hazard mitigation
  - Earthquake rapid reporting (EER)
  - Earthquake early warning (EEW)
- Seismological related research

Taiwan seismicity and tectonic





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張建興(2007)

Earthquake rapid reporting

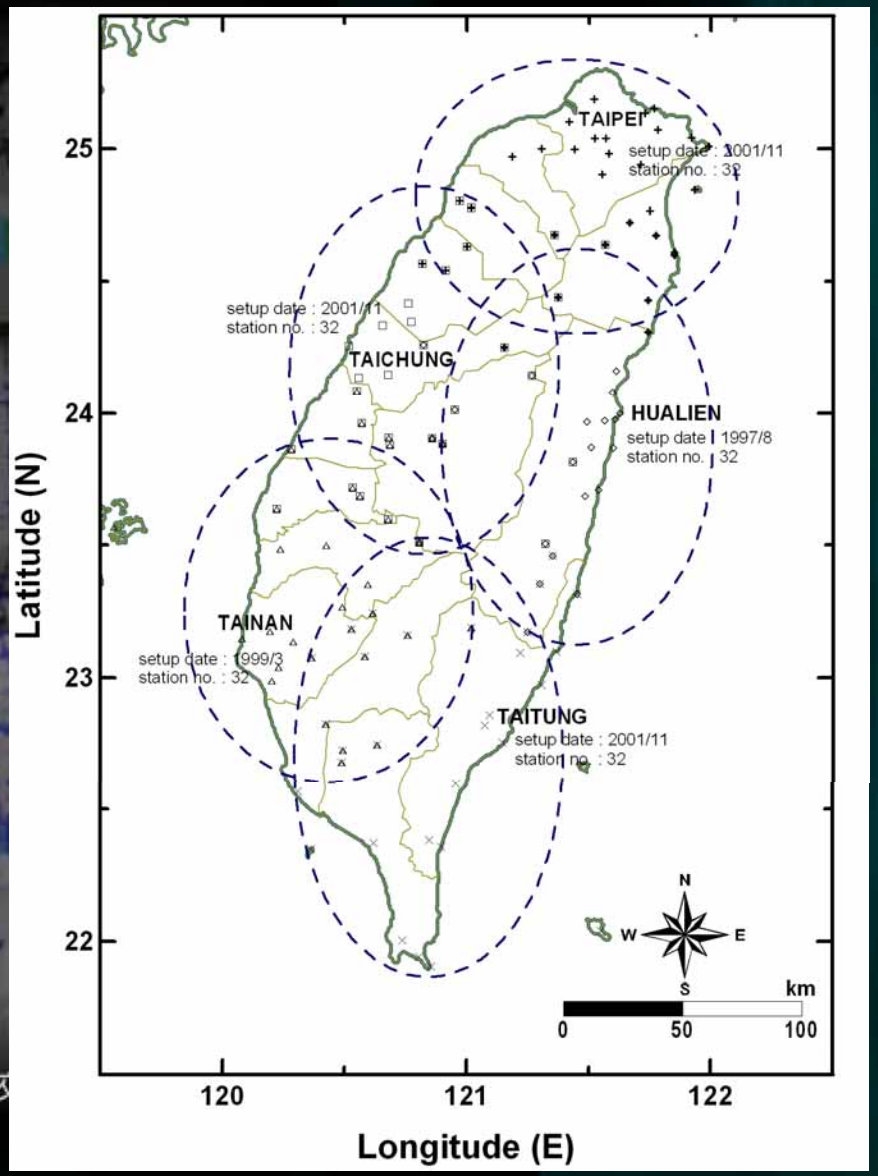
- Developed based on the real-time strong-motion network from 1995.
- Earthquake location and magnitude, and shake map of seismic intensities is automatically reported in about one minute after the occurrence of a potentially felt earthquake.
- Within 3 to 5 minutes later, an official earthquake report is disseminated to various organizations and individuals with several media, such as mobile phone SMS, Internet and public TV etc.

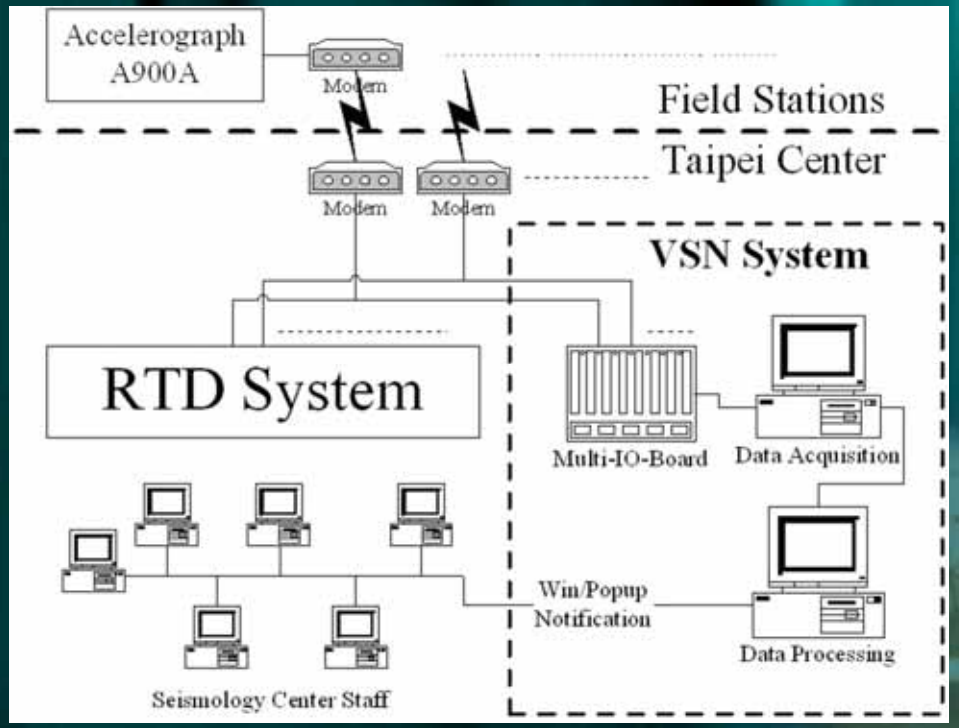
Earthquake rapid reporting

Earthquake early warning

- The ultimate goal of the earthquake early warning is to predict the arrival waves of strong earthquake shaking to people with an alarm of seconds to tens before the strong shaking arrival.
- A sub-network or virtual sub-network (VSN) approach based on the framework of real-time strong-motion network is utilized for experimentation since 2001. Currently, for earthquakes occurring in or very near Taiwan, information can be automatically reported in about 20 seconds.

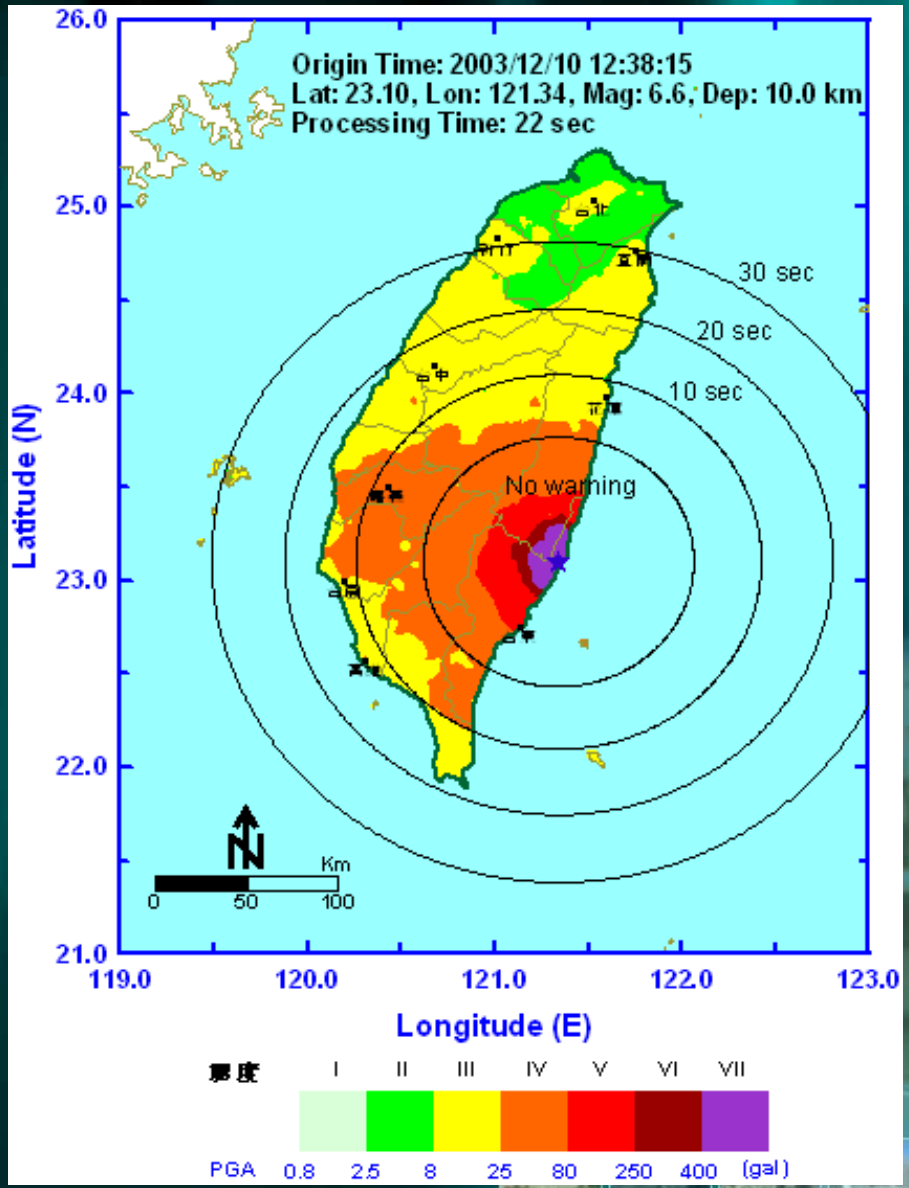
Earthquake early warning





Earthquake early warning

A case for December 10, 2003 Chenggung, Taitung earthquake (Mw 6.8). For this case, the response time of sub-network was 22 sec, which can give seconds to tens of seconds of warning time for areas 65 km away from epicenter. The maximum peak ground acceleration for warning was about 80 gals, and the Taipei metropolis having more than 30 sec warning time was about 8 gals.



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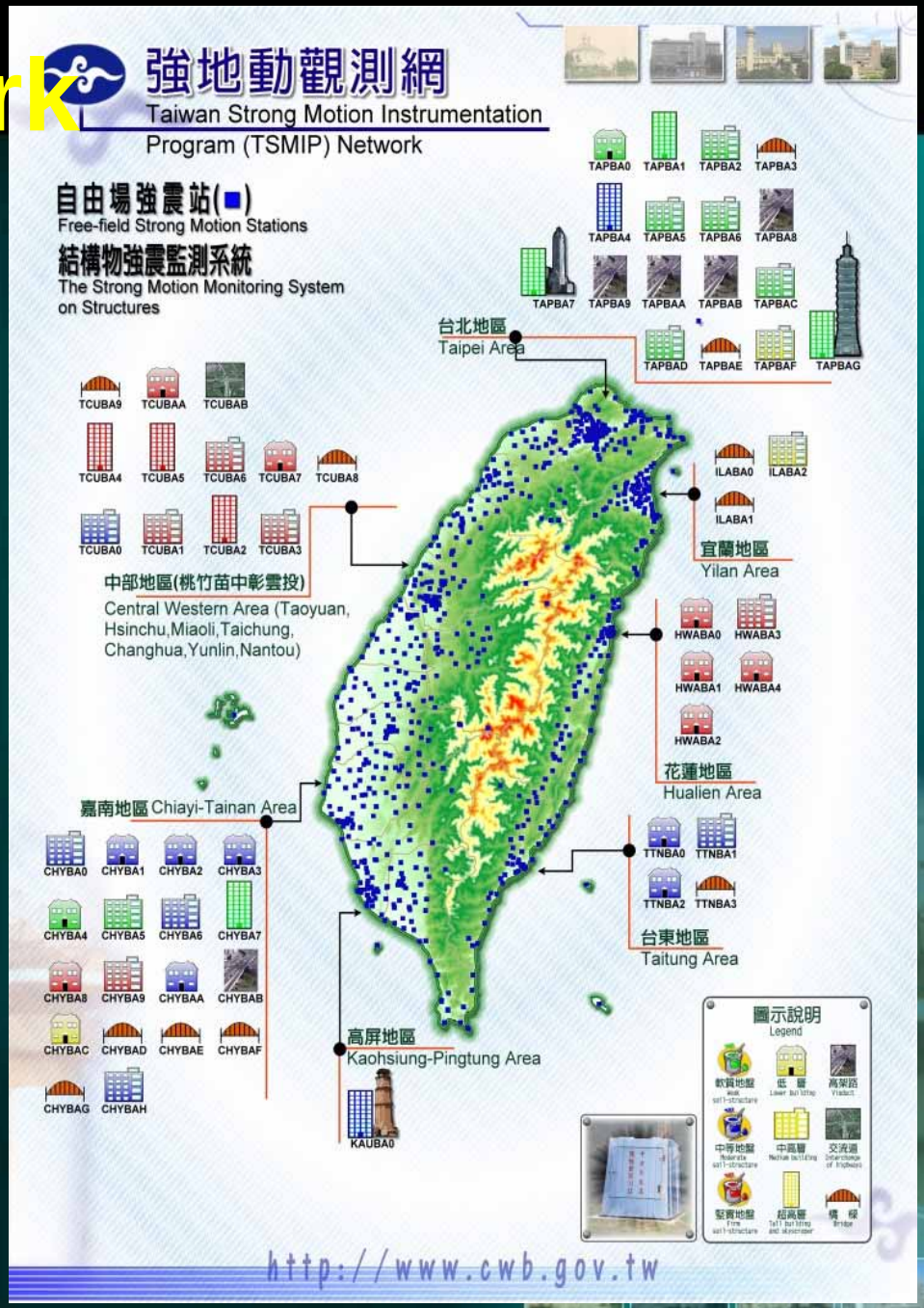
TSMIP network

- Free-field station -
  - More than 700 stations
  - accelerometer
  - Archive data by man every 4 month
- Building array -
  - 61 structures (44 buildings, 17 bridges)
  - FBA sensors and a recording system on site
  - Archive data by man or Internet



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Valuable Strong-motion records

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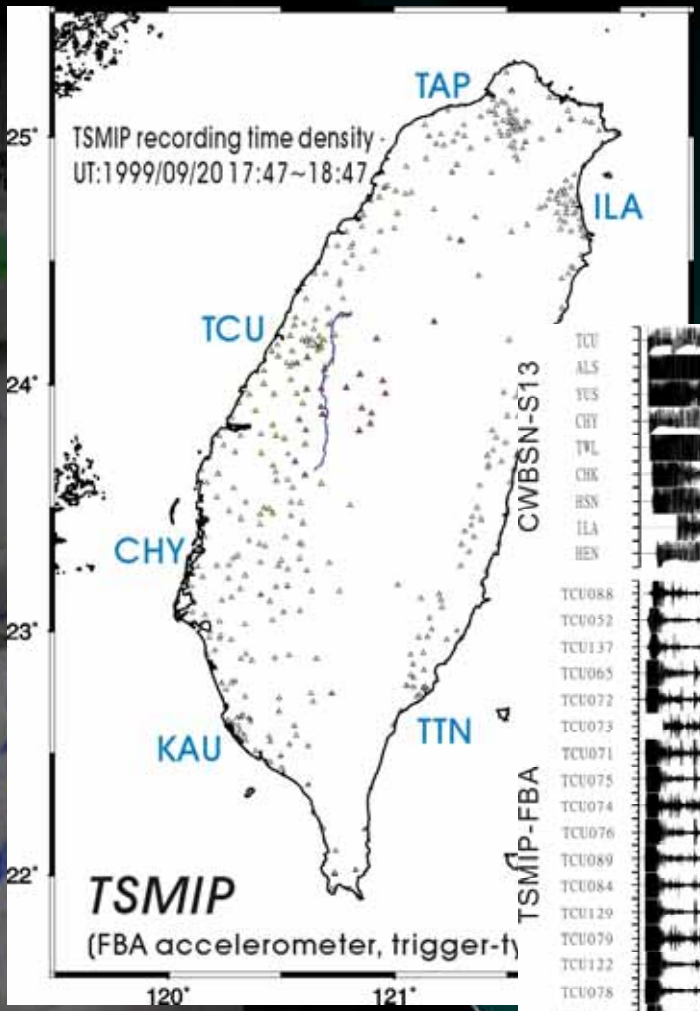

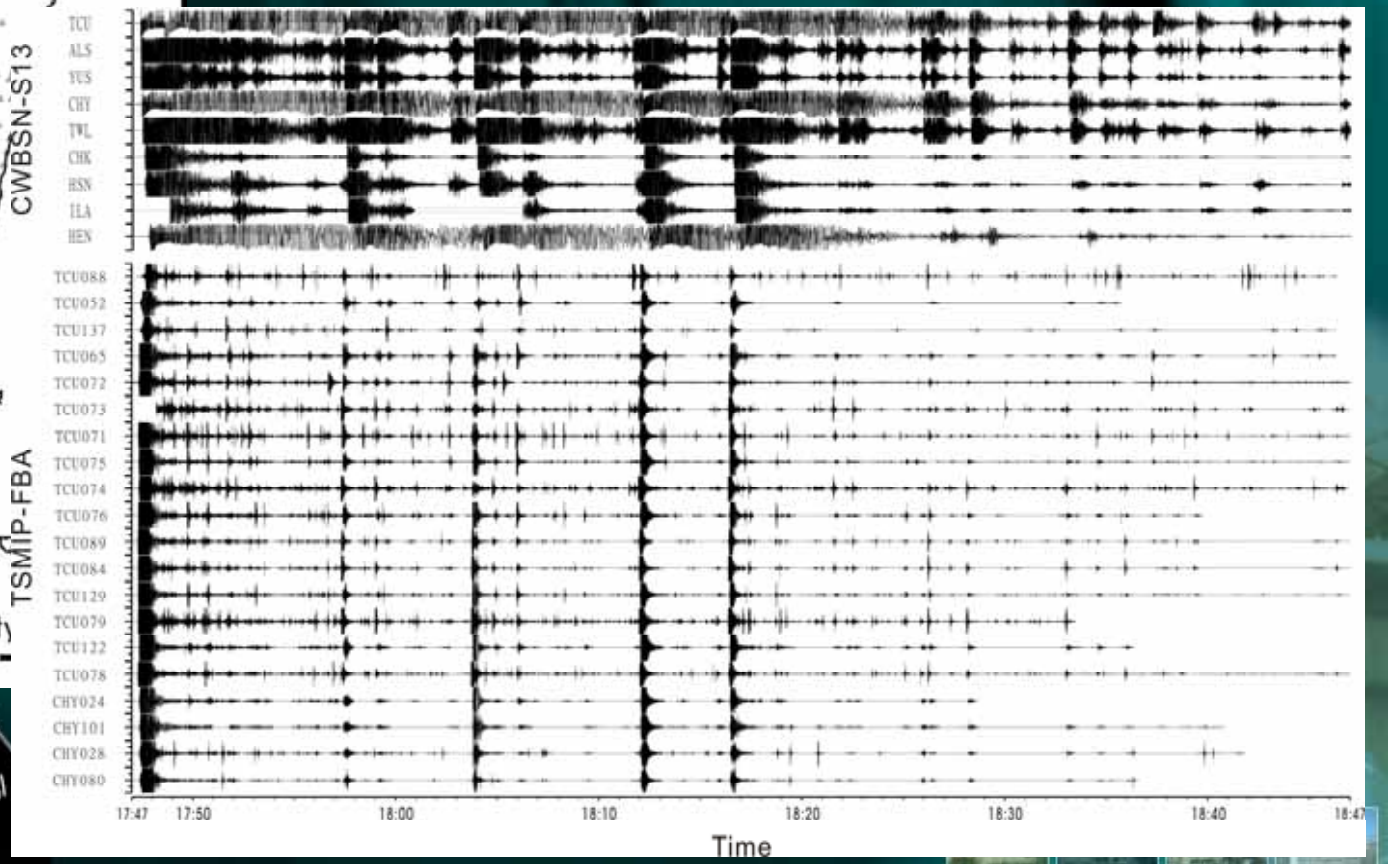

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Free-field records application

- Vibration parameter predictive equations study
  - Quick intensity estimation for earthquake early warning and rapid reporting
  - 116 EQs and more than 20000 strong-motion records are used
  - Using 2-step linear regression
- Results

$$PGA = 1.657 \times e^{1.533 \times M_L} \times r^{-1.607}$$

$$PGV = 0.003 \times e^{1.970 \times M_L} \times r^{-1.425}$$

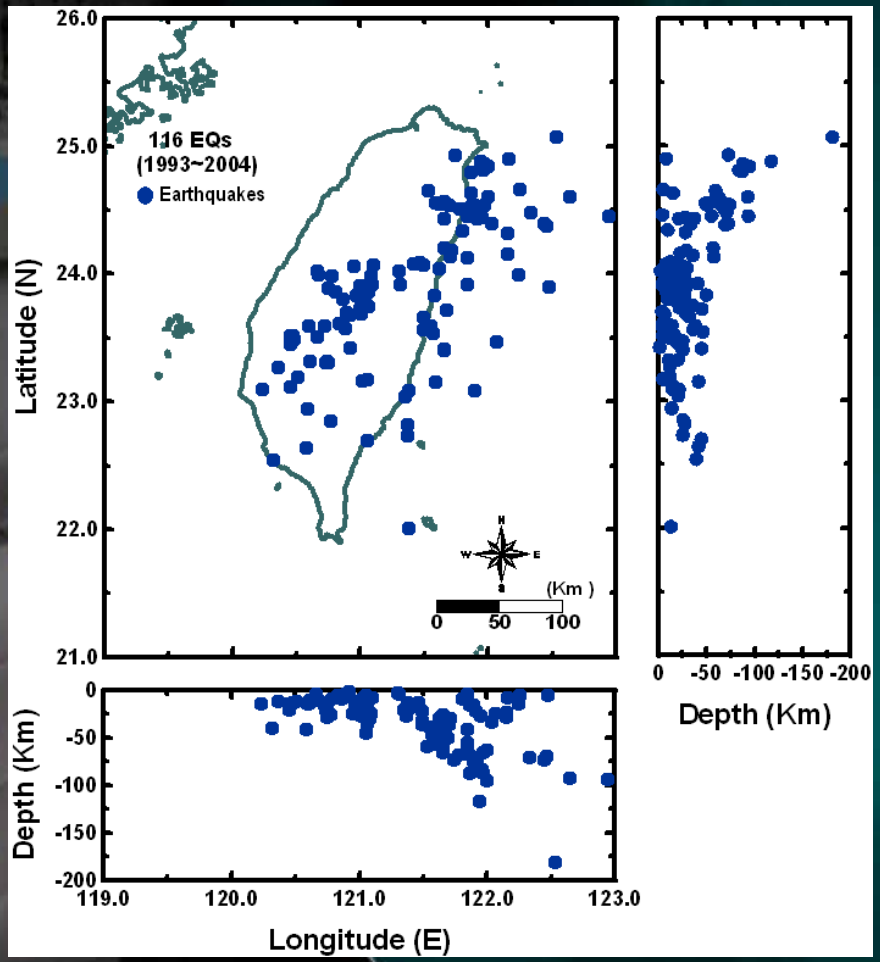
$$0.3s\_Sa = 2.739 \times e^{1.585 \times M_L} \times r^{-1.602}$$

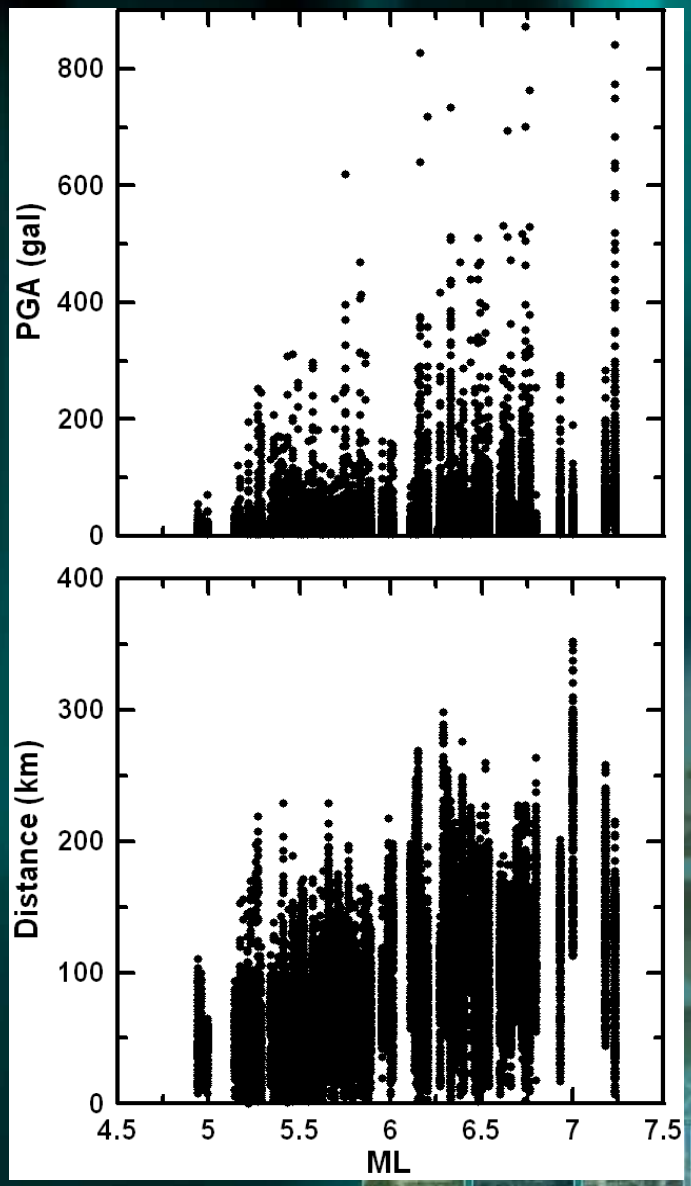
$$1.0s\_Sa = 0.002 \times e^{2.513 \times M_L} \times r^{-1.468}$$

$$3.0s\_Sa = 0.000 \times e^{2.916 \times M_L} \times r^{-1.317}$$

$$PEAK = 0.0004 f^{5.061} \times e^{2.267 f^{-0.319} \times M_L} \times r^{-(1.296+0.093 f)} \quad , \ f: 0.5\sim10\text{Hz}$$

Free-field records application





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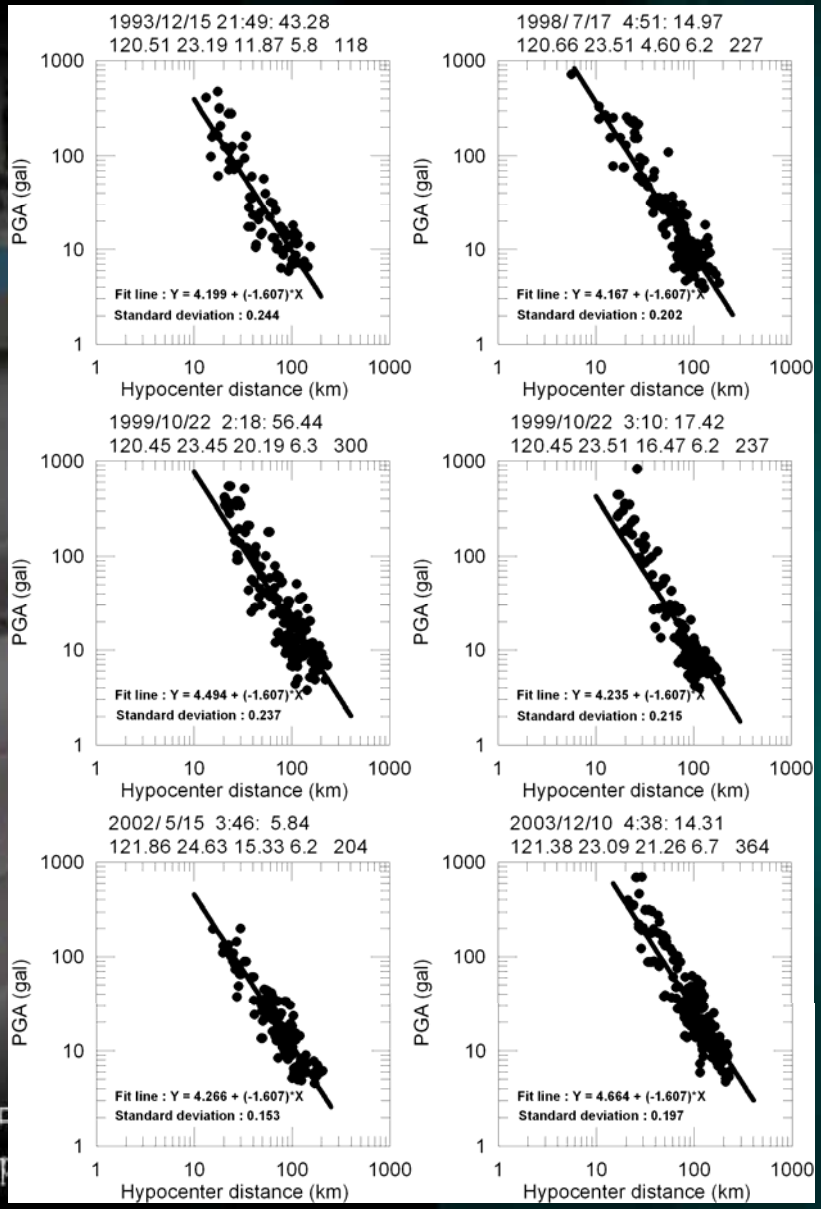
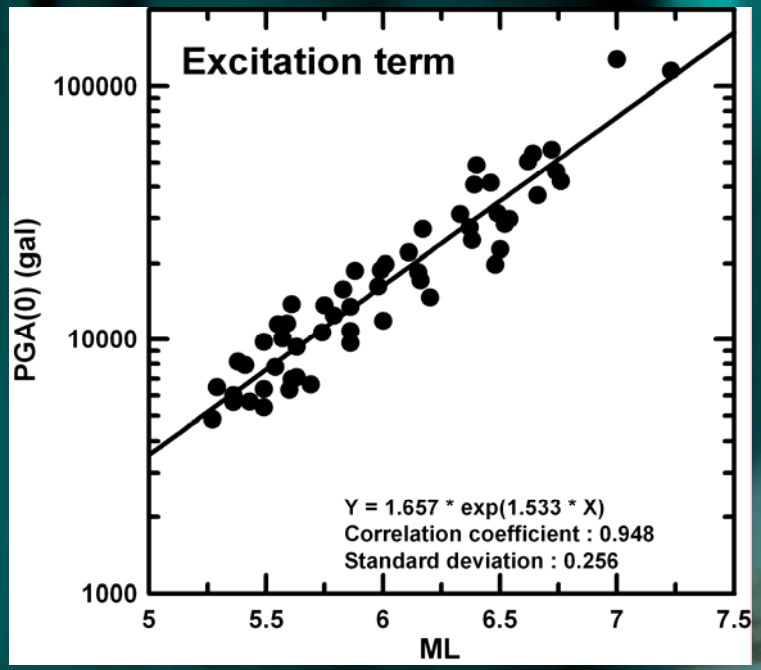
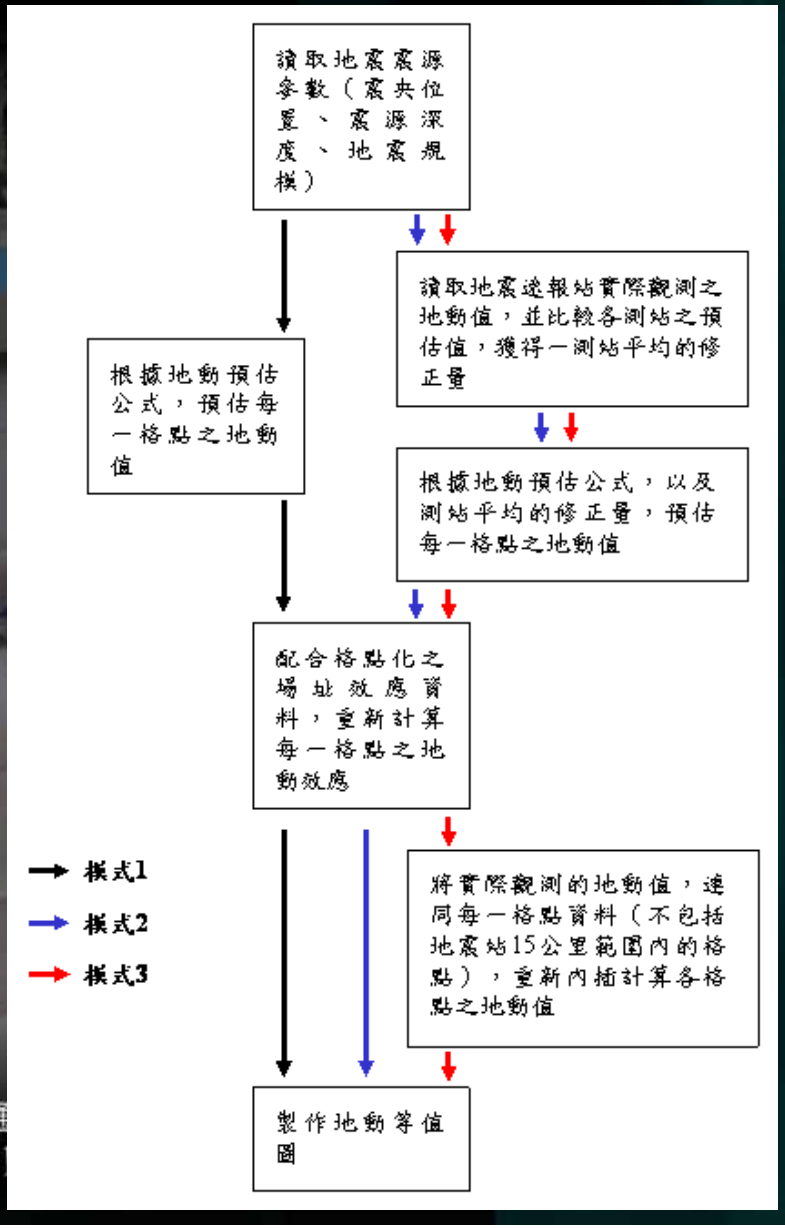
Free-field records application

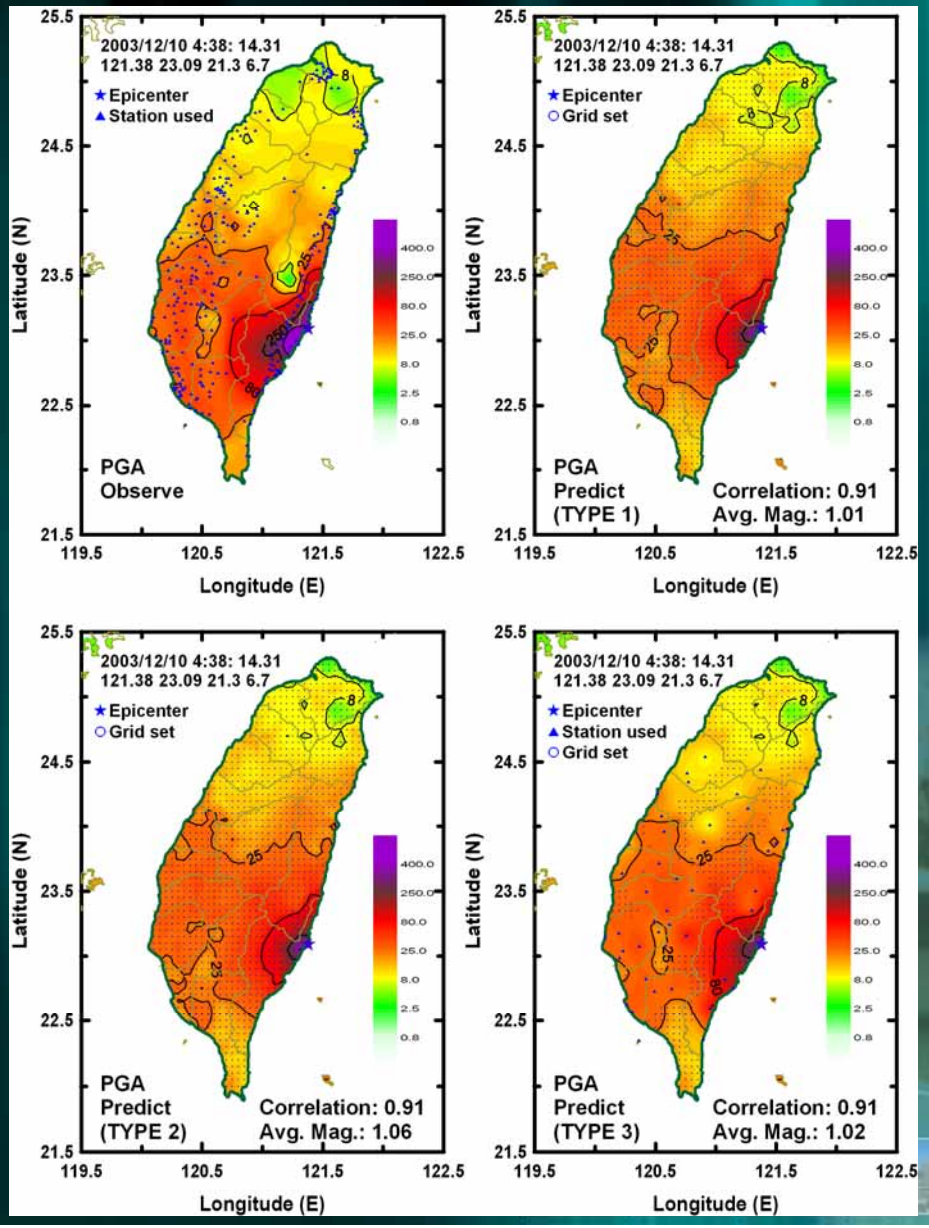




$$PGA = 1.657 \times e^{1.533 \times M} \times r^{-1.607}$$

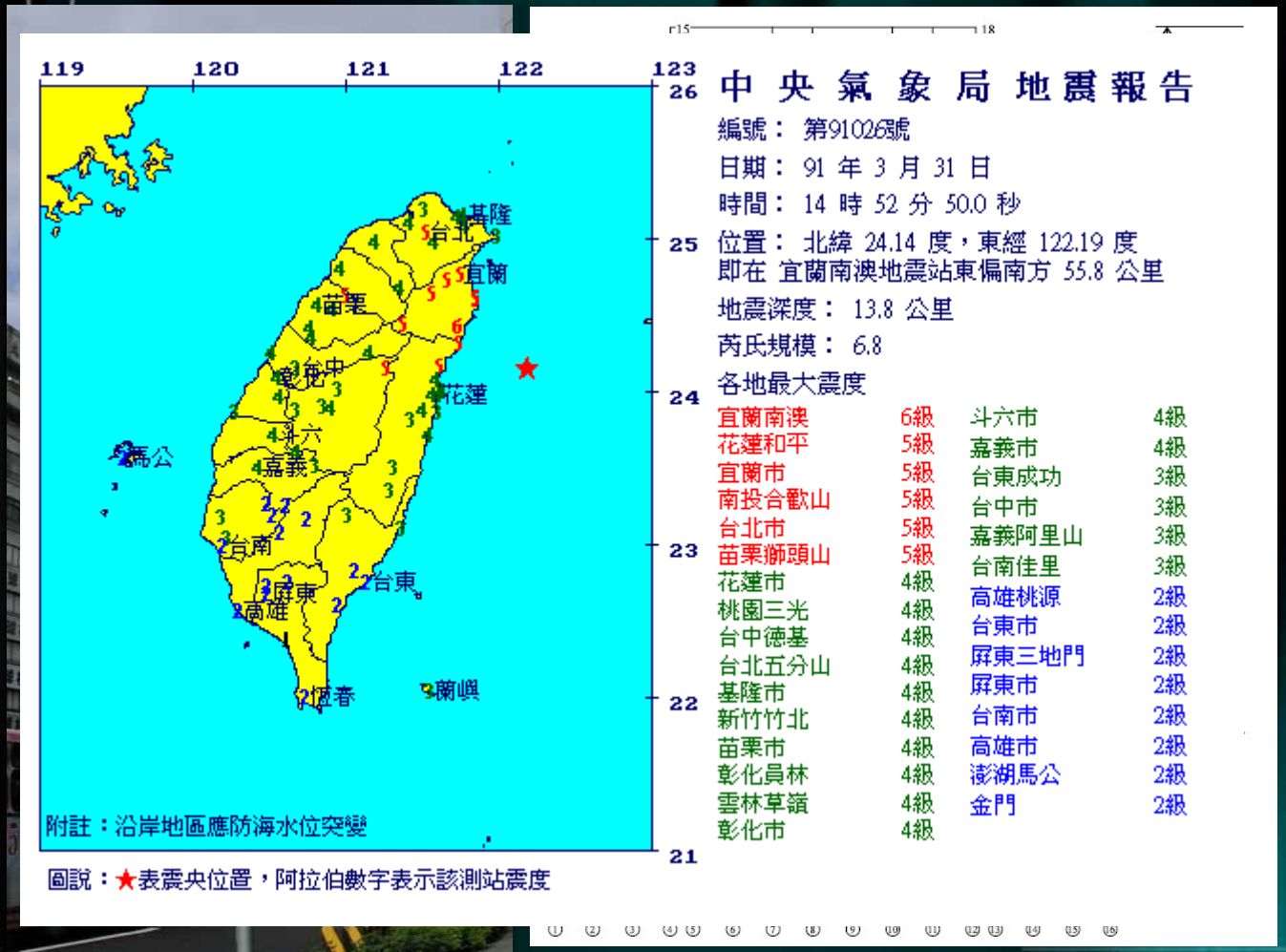
Free-field records application





Building records analysis

Taiwan power company building



中 央 氣 象 局 地 震 報 告

編號： 第91026號

日期： 91 年 3 月 31 日

時間： 14 時 52 分 50.0 秒

位置： 北緯 24.14 度，東經 122.19 度
即在 宜蘭南澳地震站東偏南方 55.8 公里

地震深度： 13.8 公里

芮氏規模： 6.8

各地最大震度

宜蘭南澳	6級	斗六市	4級
花蓮和平	5級	嘉義市	4級
宜蘭市	5級	台東成功	3級
南投合歡山	5級	台中市	3級
台北市	5級	嘉義阿里山	3級
苗栗獅頭山	5級	台南佳里	3級
花蓮市	4級	高雄桃源	2級
桃園三光	4級	台東市	2級
台中德基	4級	屏東三地門	2級
台北五分山	4級	屏東市	2級
基隆市	4級	台南市	2級
新竹竹北	4級	高雄市	2級
苗栗市	4級	澎湖馬公	2級
彰化員林	4級	金門	2級
雲林草嶺	4級		
彰化市	4級		

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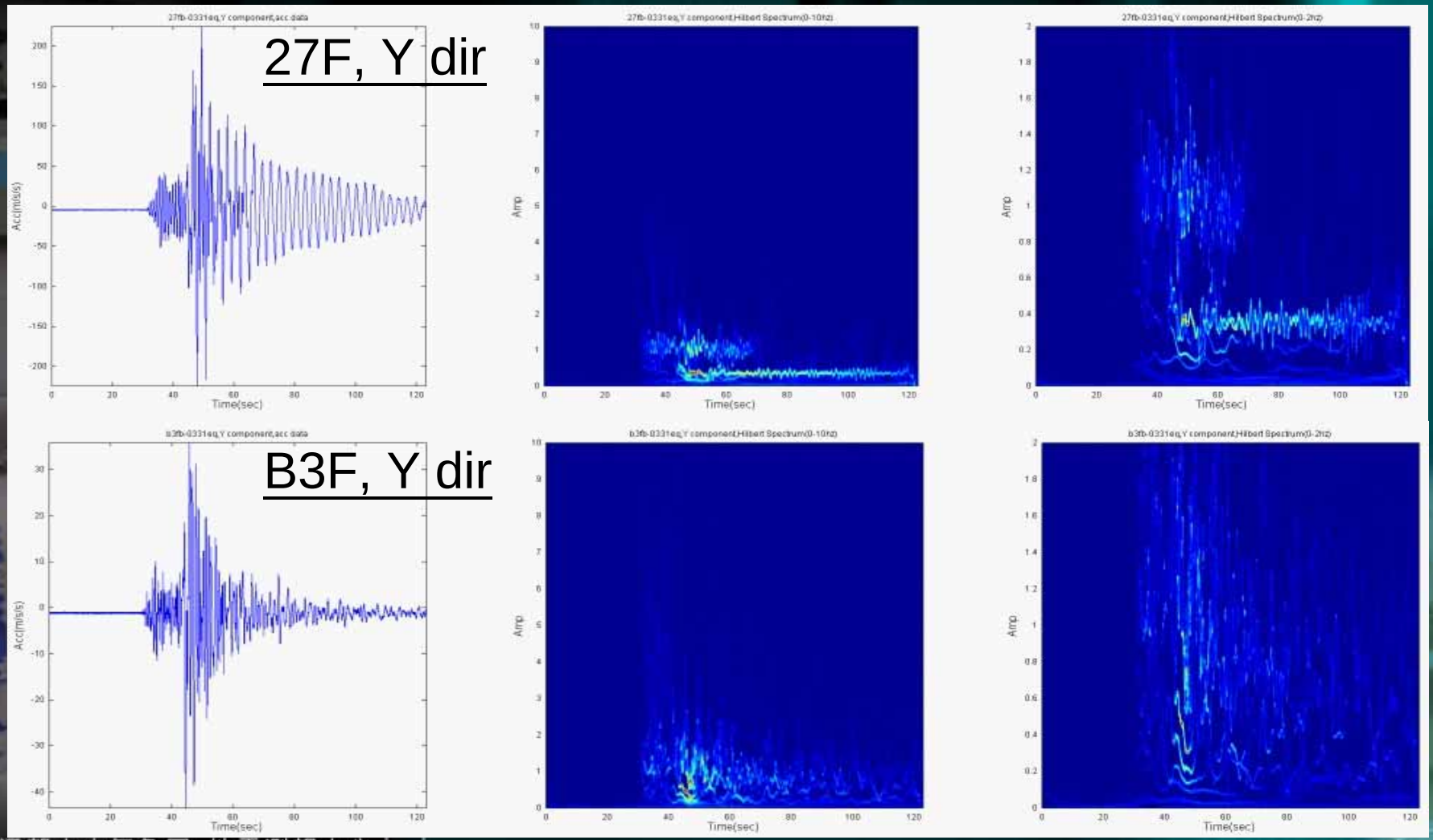
Building records analysis



蘇聖中(2007)

Future development

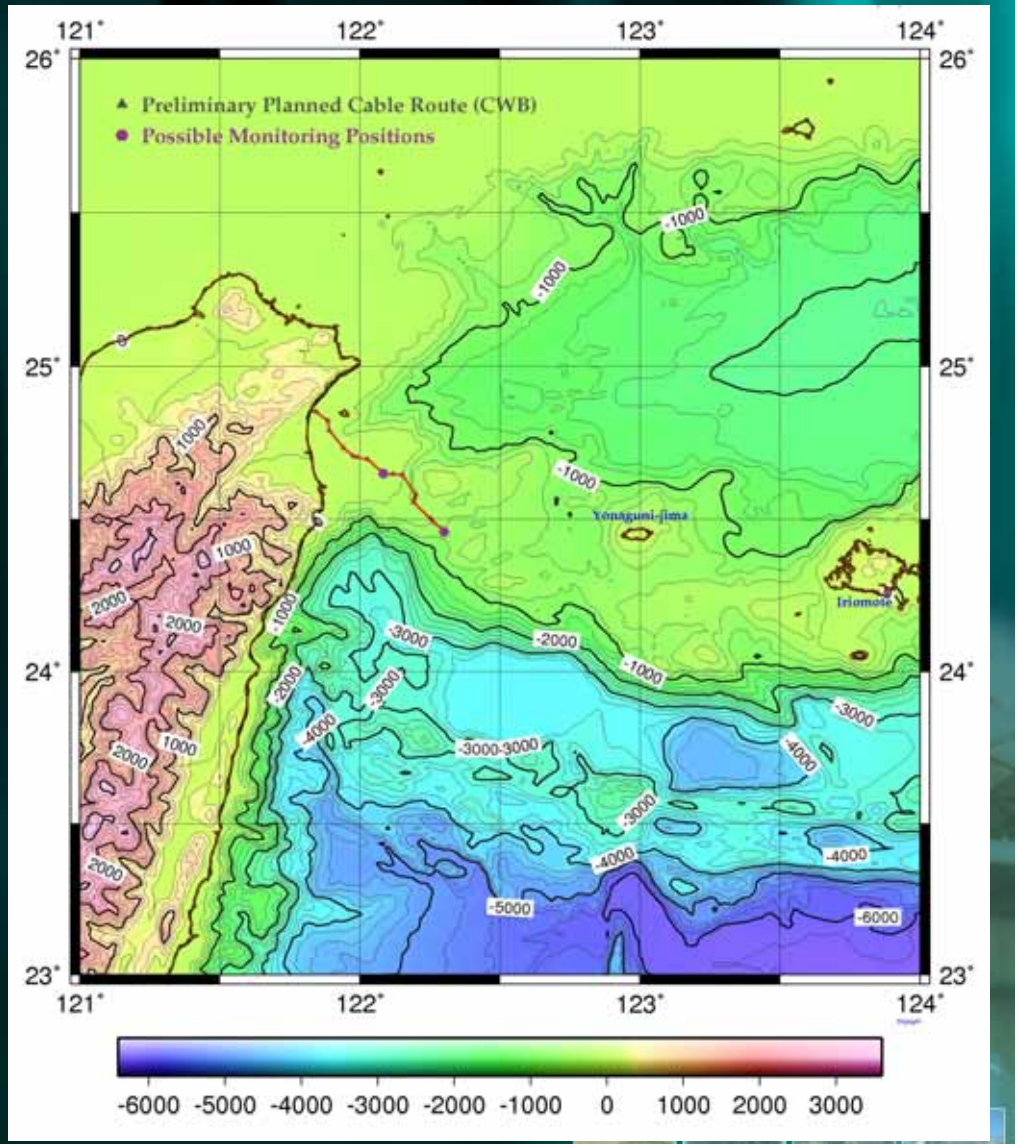
- CWBSN improvement project
- Installation of cable-based ocean bottom seismographic (OBS) network
- Building borehole seismographic stations

CWBSN improvement project

- Combine short-period with strong-motion data into 6-channel observation
- Enhance the resolution to 24 bits
- Increase the sampling rate to 100Hz
- Using TCP packet switching protocol with frame-relay network

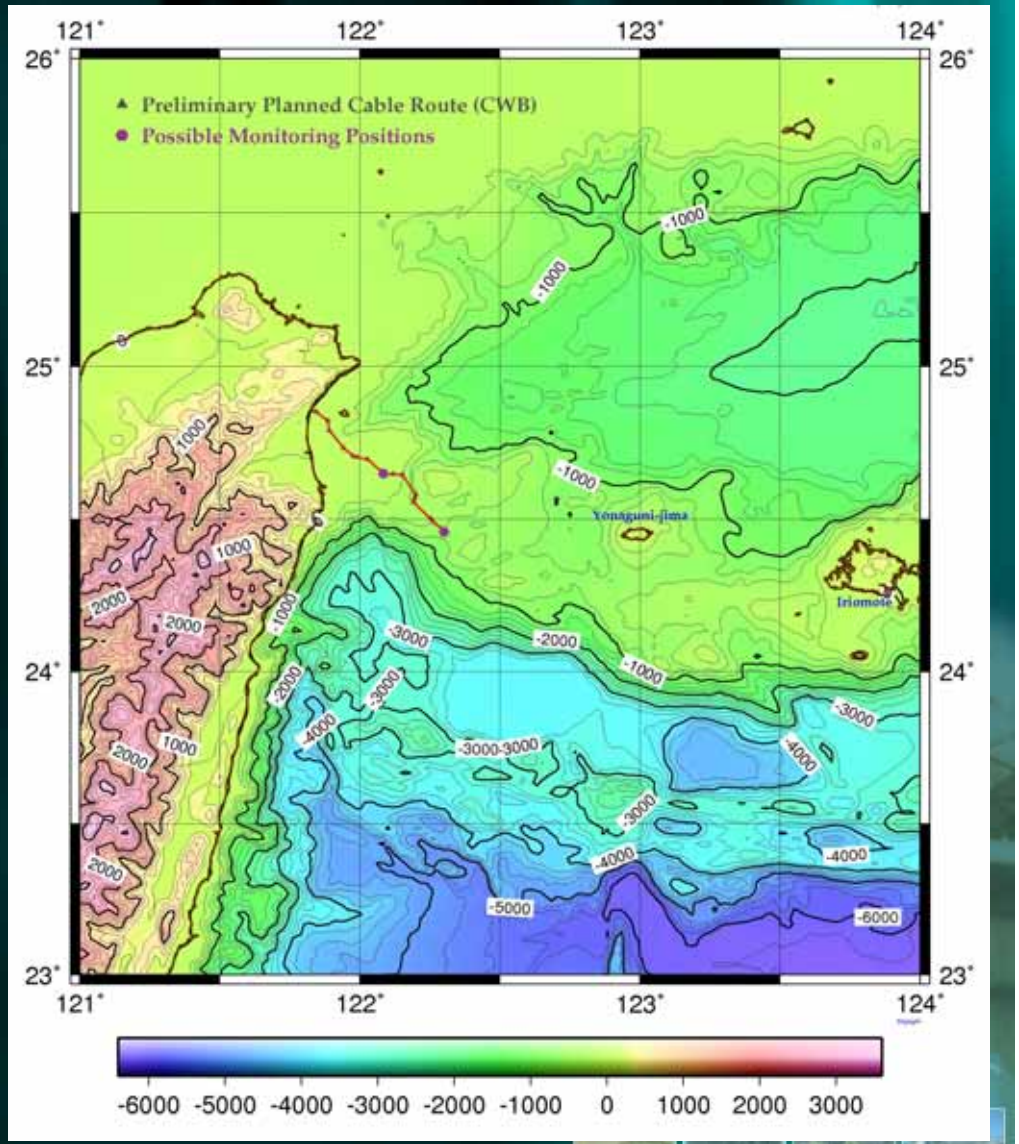
Cable-based OBS

- Objective –
  - Enhance the accuracy of earthquake position
  - Shorten the response time
- Lay the fiber cable from Toucheng (頭城)
- Cable length is about 90 Km, and the Max. ocean bottom is within 1 Km
- Install 1 or 2 node attaching various seismographs and tsuanameter



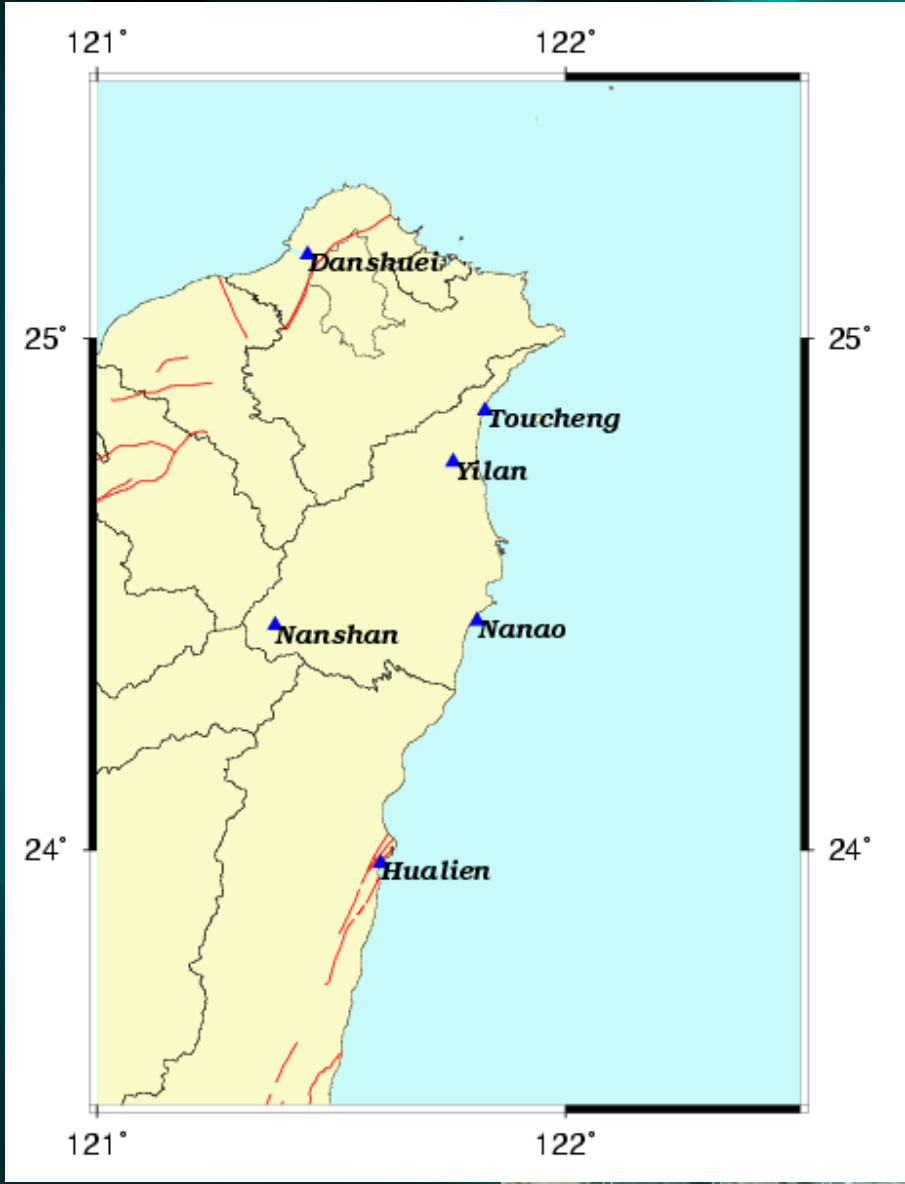
Cable-based OBS

- Plan to extend the cable and add different scientific instruments in the future
- Working period from 2008 to 2009

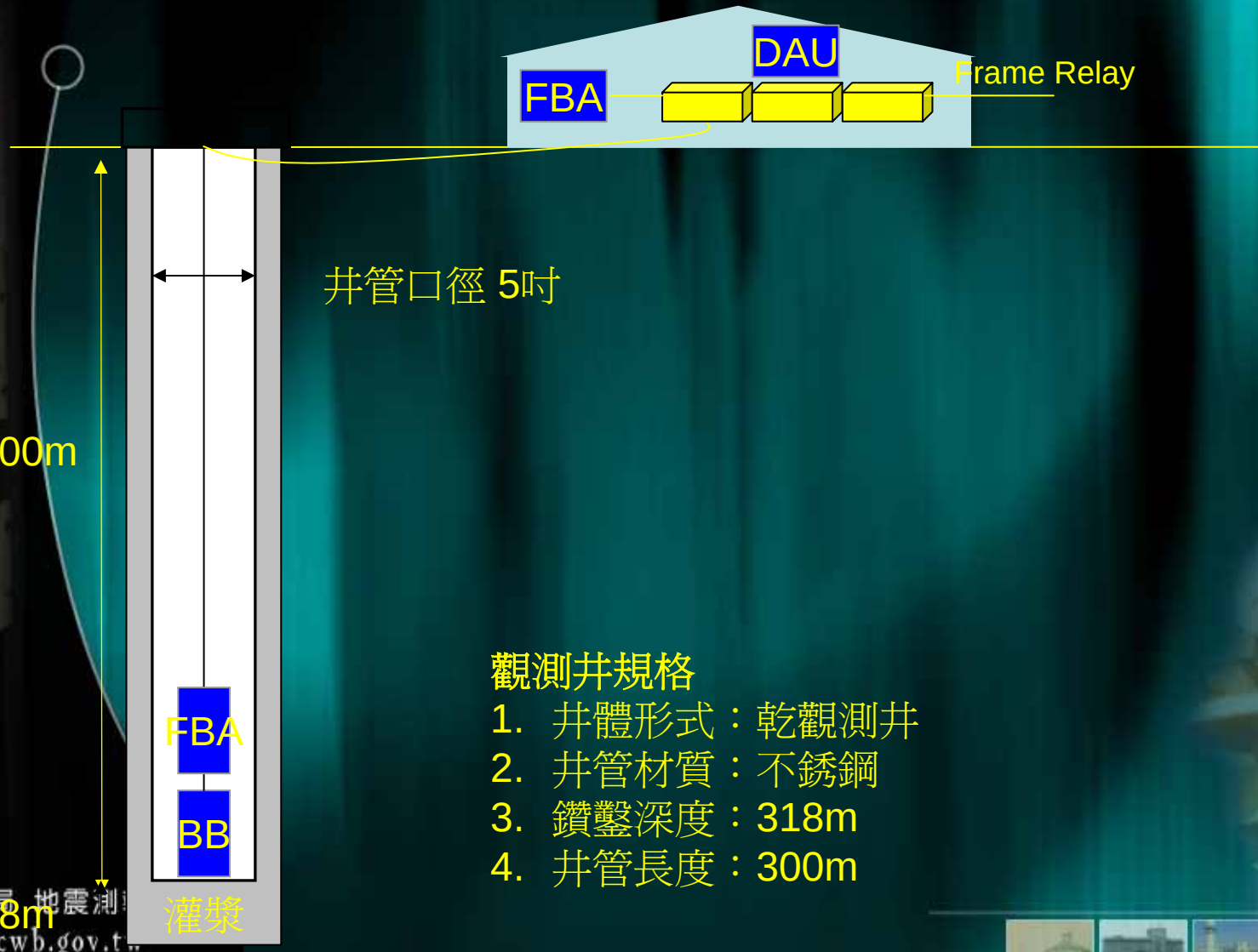


Borehole seismic stations

- Objective –
  - Joint observation with OBS stations
  - Establish the prototype of newly seismic station in Taiwan
- 6 sites are chosen to drill wells
- Max. borehole length is 300 m.
- 3 seismographic sensors are implemented, 1 borehole broadband sensor, 1 borehole FBA sensor, and 1 FBA sensor on the ground



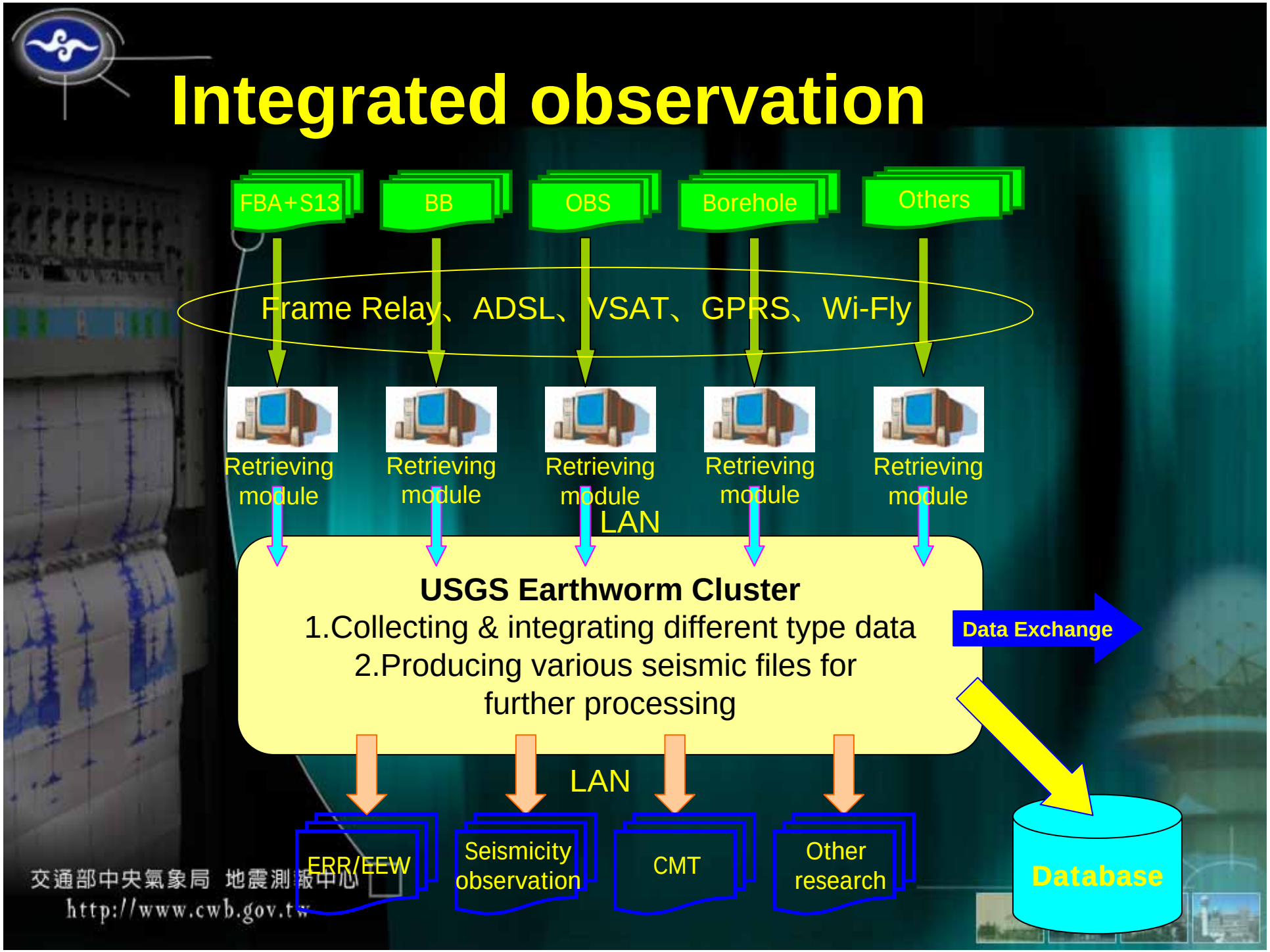
Borehole seismic stations



觀測井規格

1. 井體形式：乾觀測井
2. 井管材質：不銹鋼
3. 鑽鑿深度：318m
4. 井管長度：300m

Integrated observation



Other earthquake related observational networks at CWB

- Continuous Global Positioning System (GPS)
- Real-time groundwater observation system
- Real-time magnetic observation system

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The End

Thanks for your attention

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