Seismic network and monitoring in Taiwan

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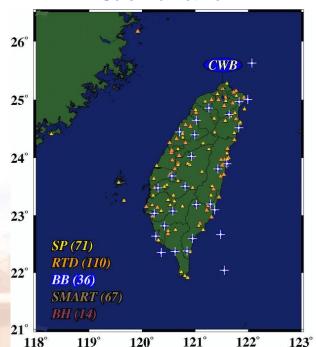# Outline

- **Introduction of the real-time seismic network in Taiwan**

- **Operations for seismic monitoring**

  - ➢ **Earthquake catalog publish**

  - ➢ **Earthquake rapid reporting**

  - ➢ **Earthquake early warning**

Seismic networks in operation

CWBSN
**Central Weather Bureau
Seismic Network**

SP (71)
RTD (110)
BB (36)
SMART (67)
BH (14)

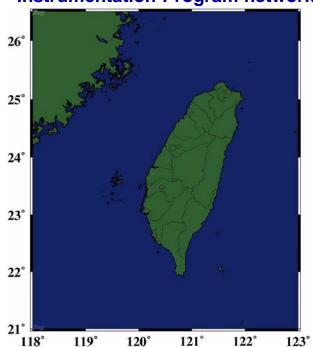**Tasks:**

- **Earthquake catalog**
- **Earthquake rapid notification and early warning**
- **Tsunami warning**
- **Seismological related research**

TSMIP
**Taiwan Strong Motion
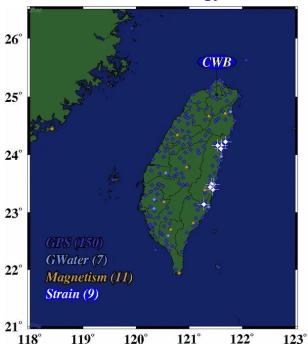Instrumentation Program network**

Tasks:

- **Strong-motion database**
- **Strong-motion seismology research**
- **Earthquake engineering application**

TGNS
**Taiwan Geophysical Network
for Seismology**

GPS (150)
GWater (7)
Magnetism (11)
Strain (9)

Tasks:

- **Geophysical database**
- **Earthquake precursor study**
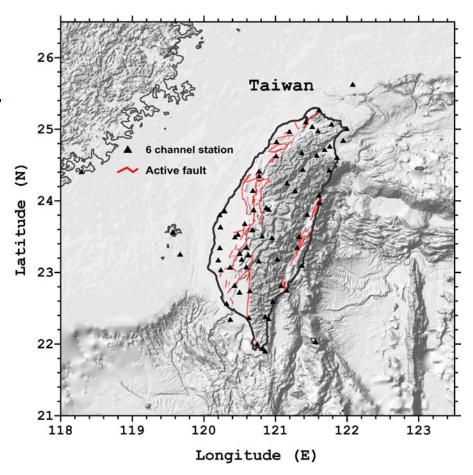- **Crustal deformation and active fault monitoring**

CWBSN framework

138 stations totally

6-channel station

- Integrate and upgrade all of Taiwan's short-period stations in 1991. Add strong-motion seismometers in stations in 1995.

- The main seismic stations for earthquake observation in Taiwan for the past 20 years.

- Totally upgrade the resolution to 24 bits in 2012.
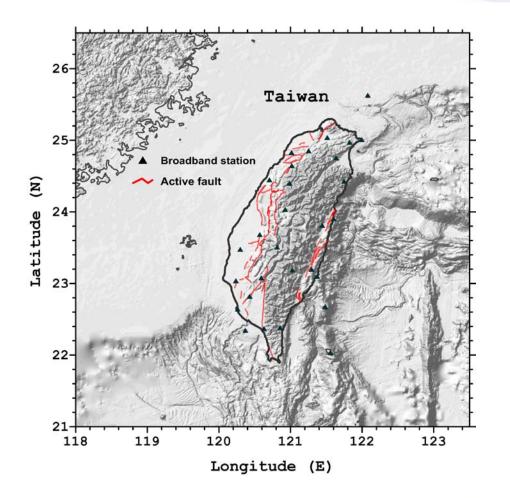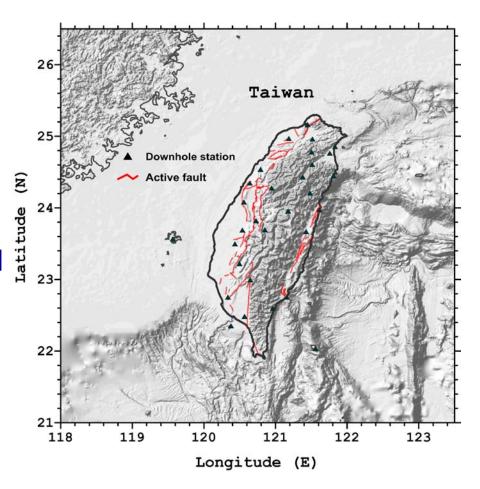
- 70 stations established.

Broadband station

◈ Start to build the stations and install broadband seismometers in 2001.

◈ High quality and resolution data are acquired for seismological related research.

◈ 29 stations established.
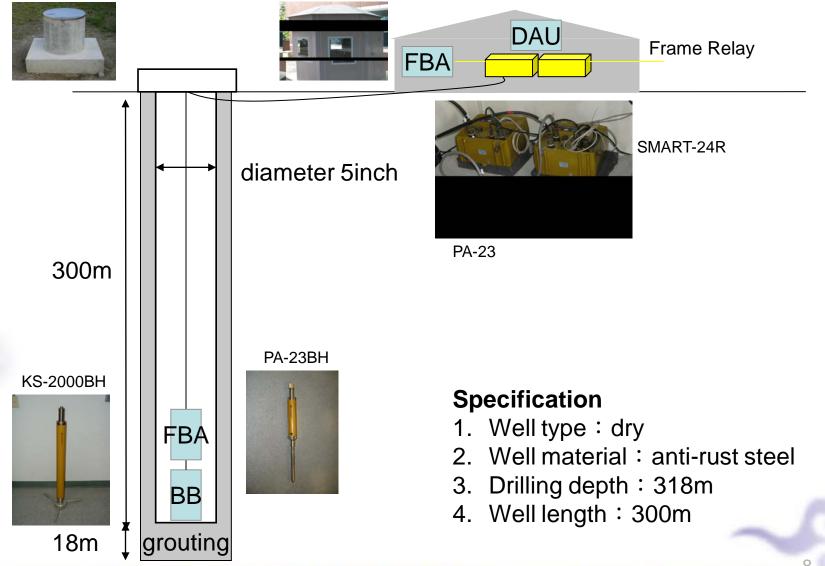
Downhole station

- Start to build the stations in 2007 in order to establish the next generation of seismic station in Taiwan.

- Borehole depth is set to 300 meter.

- 3 seismometers are installed in a station, include 1 borehole broadband sensor, 1 borehole FBA sensor, and 1 surface FBA sensor.

- 30 stations established, and plan to build 70 stations totally for the next few years.

Downhole station framework

DAU

Frame Relay

FBA

SMART-24R

PA-23

diameter 5inch

300m

PA-23BH

KS-2000BH

FBA

BB

Specification
1. Well type：dry
2. Well material：anti-rust steel
3. Drilling depth：318m
4. Well length：300m

18m

grouting

Improvement of resolution
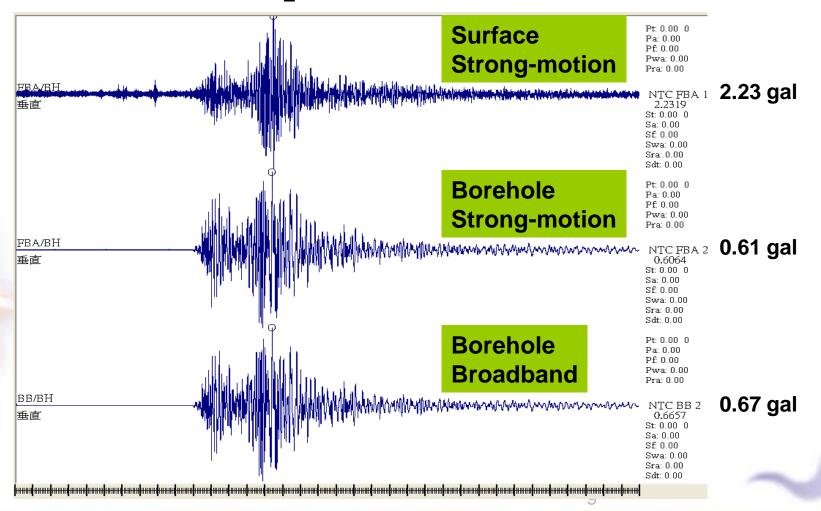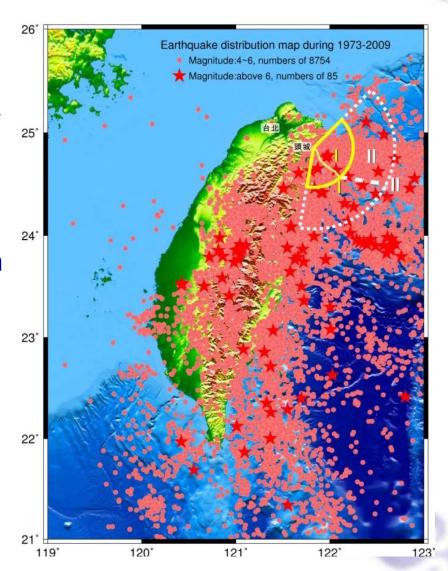
2010/3/4 8:18:52 M_L 6.4   **Toucheng station**

Surface Strong-motion — 2.23 gal

Borehole Strong-motion — 0.61 gal

Borehole Broadband — 0.67 gal
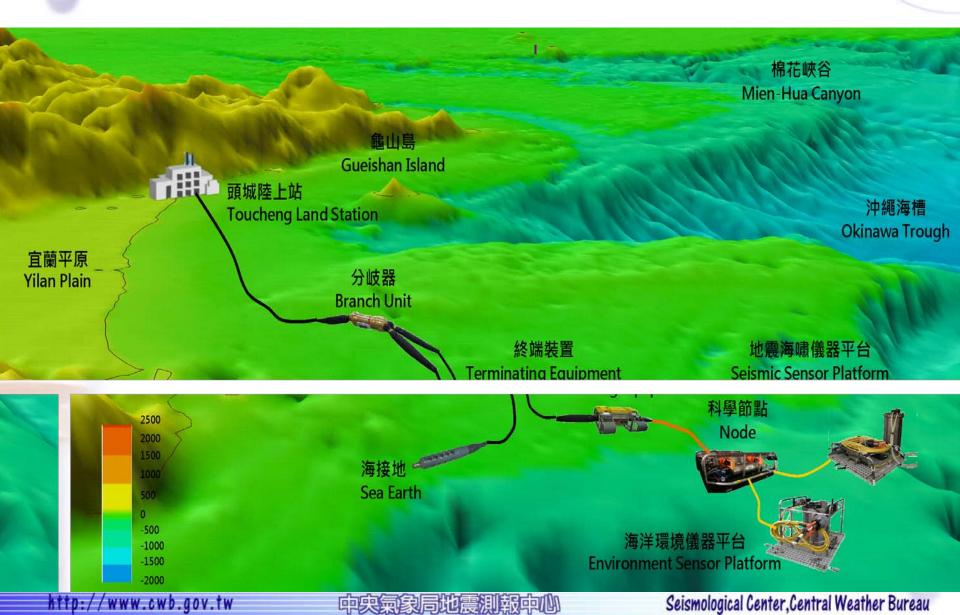
OBS station

- 1 cable based OBS station is constructed off northeastern Taiwan in 2011 to improve the capabilities of earthquake monitoring.

- Cable laid from Toucheng, Yilan county. The cable length is about 45 km, and the water depth of station is about 300 meter.

- 1 broadband sensor and 1 FBA sensor are installed.

- Plan to extend the cable length and add more OBS in the future.

Earthquake distribution map during 1973-2009
Magnitude:4~6, numbers of 8754
Magnitude:above 6, numbers of 85

OBS system framework

棉花峽谷
Mien-Hua Canyon

龜山島
Gueishan Island

頭城陸上站
Toucheng Land Station

沖繩海槽
Okinawa Trough

宜蘭平原
Yilan Plain

分岐器
Branch Unit

終端裝置
Terminating Equipment

地震海嘯儀器平台
Seismic Sensor Platform

科學節點
Node

海接地
Sea Earth

海洋環境儀器平台
Environment Sensor Platform

2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000

OBS waveform

2012/8/31 12:47 M_w 7.6

OBS Broadband

Borehole Broadband

Land station

Real-time data integration

Strong-motion, Broadband, Short period

Real-time data → Tankplayer → **WAVE_RING** → Waveserver → Tank

Earthworm

Pick_eew → Processing program

Waveman2disk → Specific format data → Processing program

SAC, MiniSeed, SUDS, TANK, CWB24
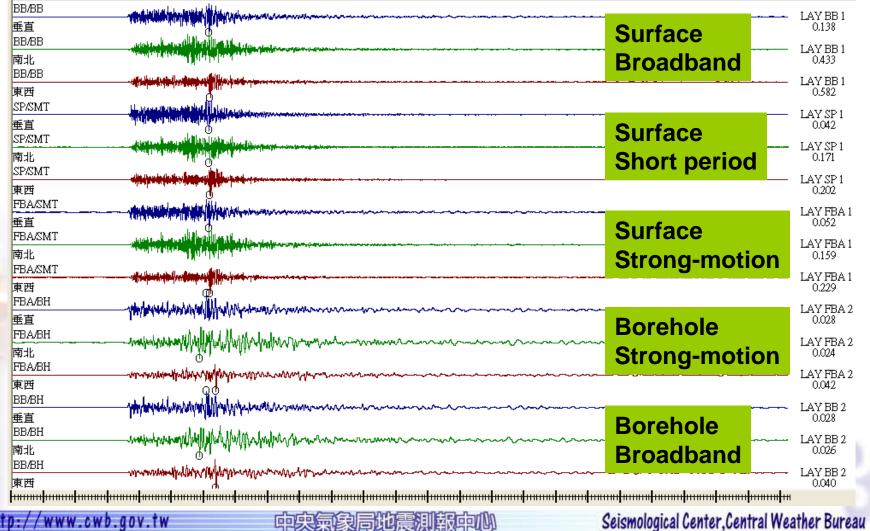
(D.-Y. Chen)

Multi-channel waveform

2010/3/4 16:16:16 M_L 5.7　　　　　**Lanyu station**

Surface Broadband

Surface Short period

Surface Strong-motion

Borehole Strong-motion

Borehole Broadband

Operations for seismic monitoring

- **Earthquake catalog publish**

- **Earthquake rapid reporting**
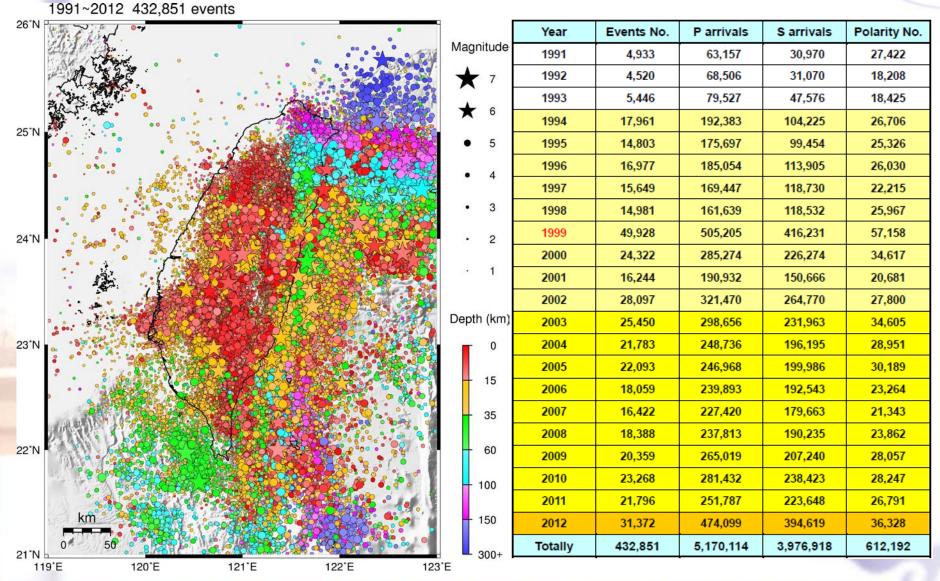
- **Earthquake early warning**

Taiwan earthquake catalog

1991~2012 432,851 events

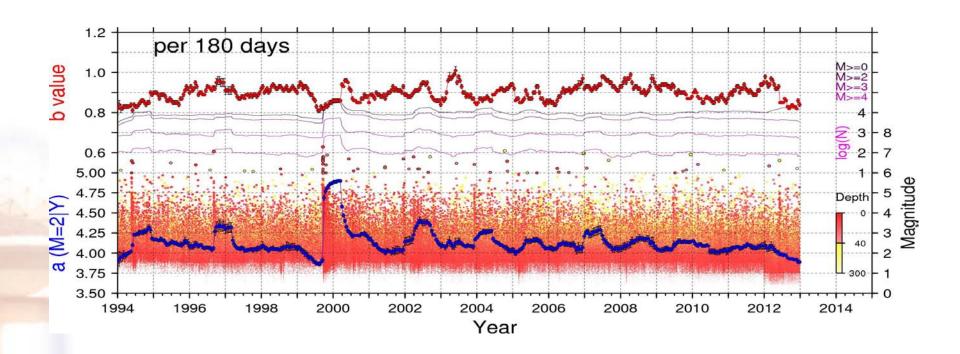| Year	Events No.	P arrivals	S arrivals	Polarity No.
1991	4,933	63,157	30,970	27,422
1992	4,520	68,506	31,070	18,208
1993	5,446	79,527	47,576	18,425
1994	17,961	192,383	104,225	26,706
1995	14,803	175,697	99,454	25,326
1996	16,977	185,054	113,905	26,030
1997	15,649	169,447	118,730	22,215
1998	14,981	161,639	118,532	25,967
1999	49,928	505,205	416,231	57,158
2000	24,322	285,274	226,274	34,617
2001	16,244	190,932	150,666	20,681
2002	28,097	321,470	264,770	27,800
2003	25,450	298,656	231,963	34,605
2004	21,783	248,736	196,195	28,951
2005	22,093	246,968	199,986	30,189
2006	18,059	239,893	192,543	23,264
2007	16,422	227,420	179,663	21,343
2008	18,388	237,813	190,235	23,862
2009	20,359	265,019	207,240	28,057
2010	23,268	281,432	238,423	28,247
2011	21,796	251,787	223,648	26,791
2012	31,372	474,099	394,619	36,328
Totally	432,851	5,170,114	3,976,918	612,192

Seismicity observation
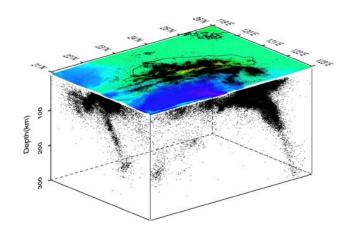
Measurement the seismicity changes by values a and b
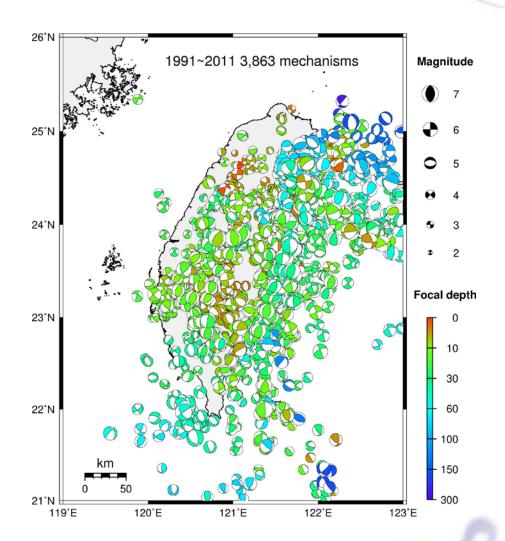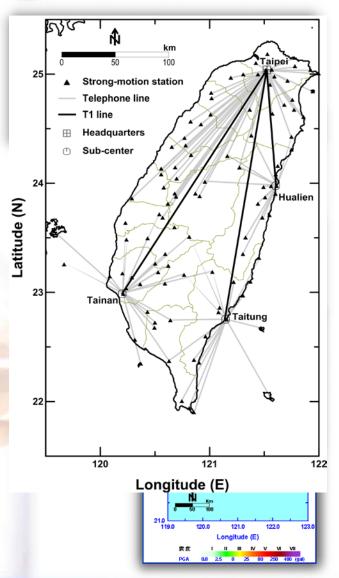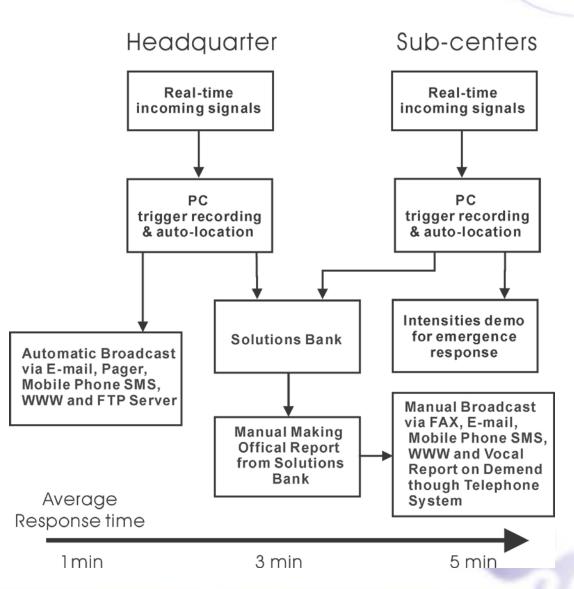

(C.-H. Chang)

Seismogenic structure study

1991~2011 3,863 mechanisms

(C.-H. Chang)

Earthquake rapid notification

Headquarter

Sub-centers

Real-time incoming signals

Real-time incoming signals

PC trigger recording & auto-location

PC trigger recording & auto-location

Solutions Bank

Intensities demo for emergence response

Automatic Broadcast via E-mail, Pager, Mobile Phone SMS, WWW and FTP Server

Manual Making Offical Report from Solutions Bank

Manual Broadcast via FAX, E-mail, Mobile Phone SMS, WWW and Vocal Report on Demend though Telephone System

Average Response time

1 min   3 min   5 min

Earthquake report statistics

2006~2012
984 Events

984 EQs
(2006/1~2012/12)
● Earthquake
— Difference
related to catalog

5.08 ± 6.21 km

Epicenter deviation :
5.08 +- 6.21 km

Depth deviation :
4.73 +- 5.64 km

4.73 ± 5.64 km
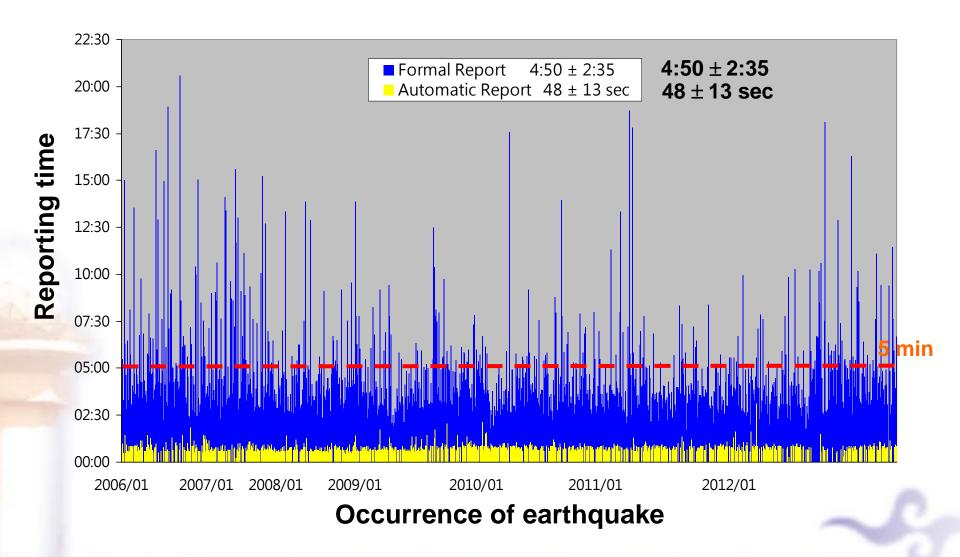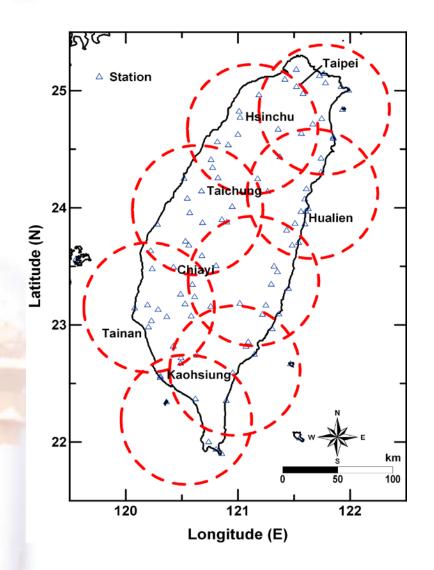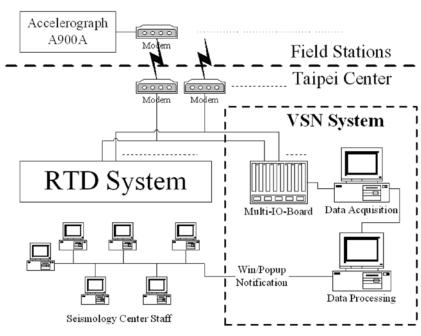
Reporting time
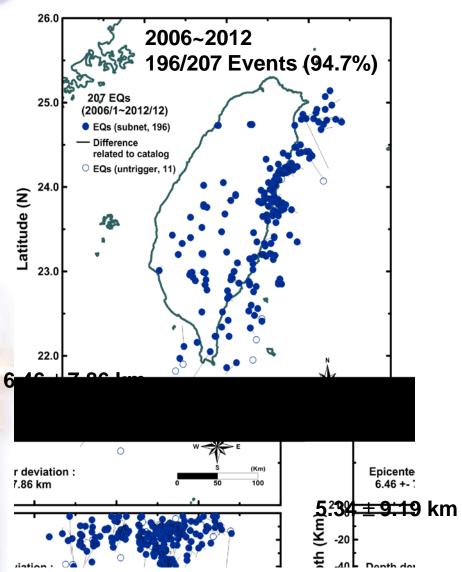
Virtual Sub-Network for EEW

EEW Capability

2006~2012
196/207 Events (94.7%)

207 EQs
(2006/1~2012/12)
● EQs (subnet, 196)
— Difference
related to catalog
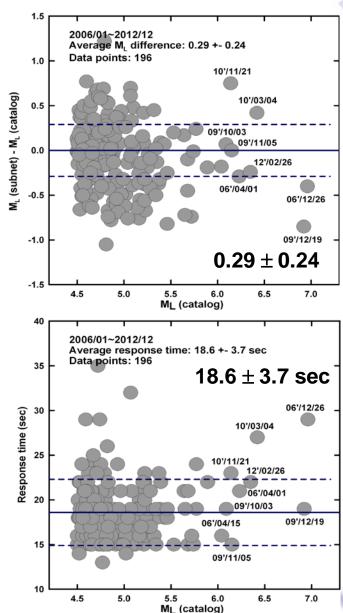○ EQs (untrigger, 11)

0.29 ± 0.24

18.6 ± 3.7 sec

5.34 ± 9.19 km

Promotion plan for EEW in Taiwan

◈ For promoting and testing the EEW application in Taiwan, a joint program in cooperation with CWB and National Science and Technology Center for Disaster Reduction (NCDR) was performed.

◈ Currently, the organizations of application include elementary schools, power plants, transportation networks, and disaster prevention agencies.
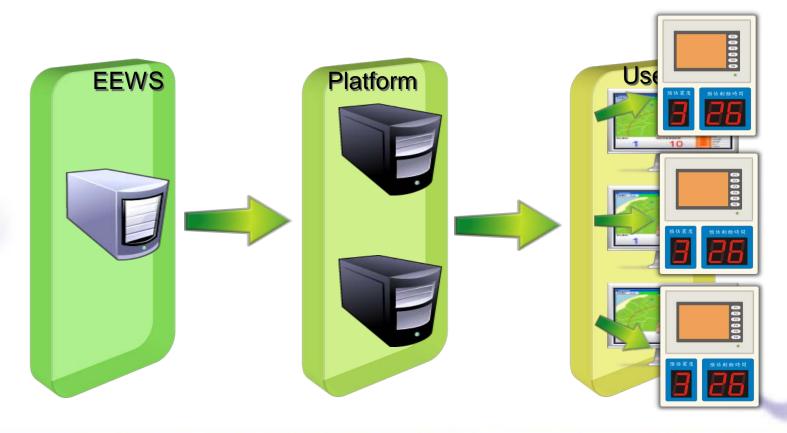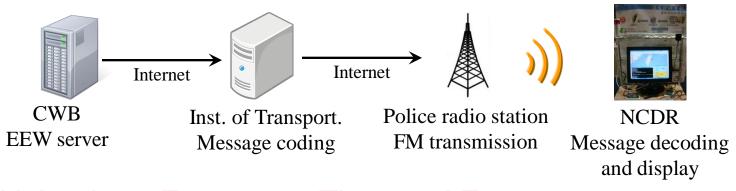
Message disseminative platform

- **Internet as the main medium**

- **Active platform**
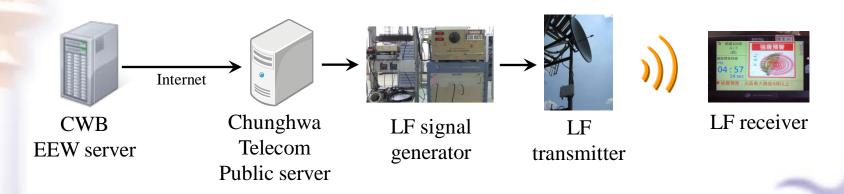
- **Client-server architecture**

EEWS

Platform

User

Transmission test

- ## Using the Radio Data System

| CWB EEW server | Inst. of Transport. Message coding | Police radio station FM transmission | NCDR Message decoding and display |

- ## Using Low-Frequency Time and Frequency Broadcasting System

CWB EEW server — Chunghwa Telecom Public server — LF signal generator — LF transmitter — LF receiver

Application of EEW 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, NCREE, and CWB.
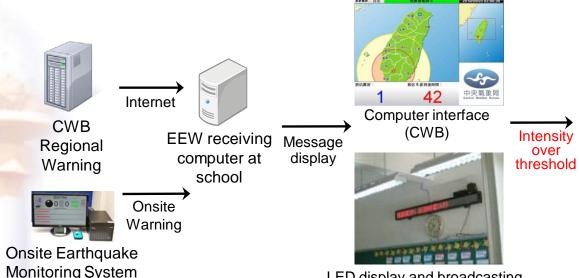
Metropolitan area
Fanghe junior high school, Taipei

High seismicity area
Yilan elementary school , Yilan

High earthquake potential area
National Chungcheng University, Chiayi
Gangping elementary school, Chiayi

CWB Regional Warning

Internet

EEW receiving computer at school

Onsite Warning

Onsite Earthquake Monitoring System

Message display

Computer interface (CWB)

LED display and broadcasting in classrooms

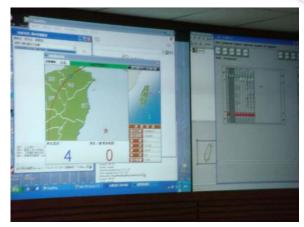Intensity over threshold
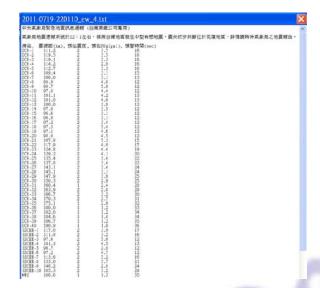
Activate emergency responses

Application of EEW

◆ **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.

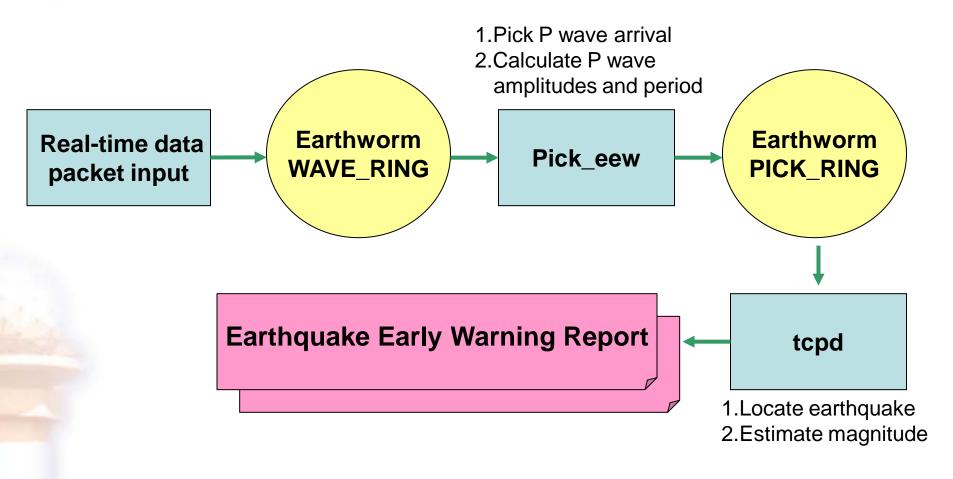EEW message for Taiwan High Speed Rail

Advanced EEW procedure developed

1. Pick P wave arrival
2. Calculate P wave amplitudes and period

Real-time data packet input → **Earthworm WAVE_RING** → **Pick_eew** → **Earthworm PICK_RING**

Earthquake Early Warning Report ← **tcpd**

1. Locate earthquake
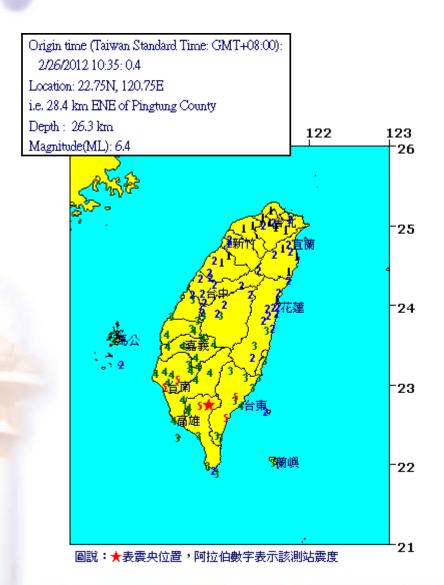2. Estimate magnitude

$M_{\tau c} = 4.218 * \log10(\tau_c) + 6.166$ (Wu et al., 2010)

$M_{Pd} = 3.905 + 2.198 * \log10(Pd) + 2.703 * \log10(R)$ (Hsiao et al., 2010) (D.-Y. Chen)
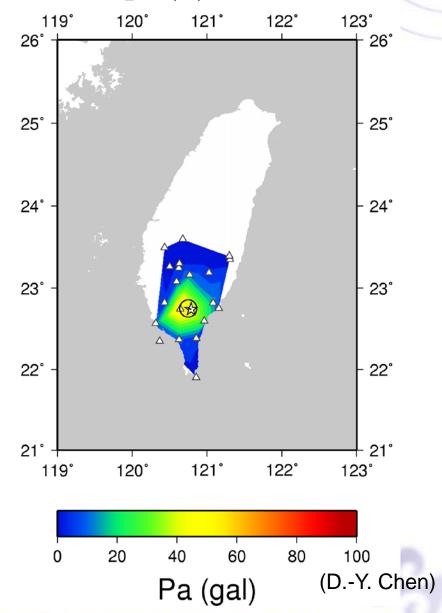
Example

Origin time (Taiwan Standard Time: GMT+08:00):
2/26/2012 10:35: 0.4
Location: 22.75N, 120.75E
i.e. 28.4 km ENE of Pingtung County
Depth : 26.3 km
Magnitude(ML): 6.4

圖說：★表震央位置，阿拉伯數字表示該測站震度

20120226023527_n26.rep Mpd=6.23, Mtc=6.32, Time=27.05

Pa (gal)

(D.-Y. Chen)

The End

Thank you for your attention!