Introduction to the Earthquake Monitoring in Taiwan

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Outline

- Tectonic setting of Taiwan
- Earthquake Monitoring Systems
- Rapid Earthquake Notification
  - Earthquake information
  - Earthquake Early Warning (EEW)
  - Focal Mechanism
- Data Sharing
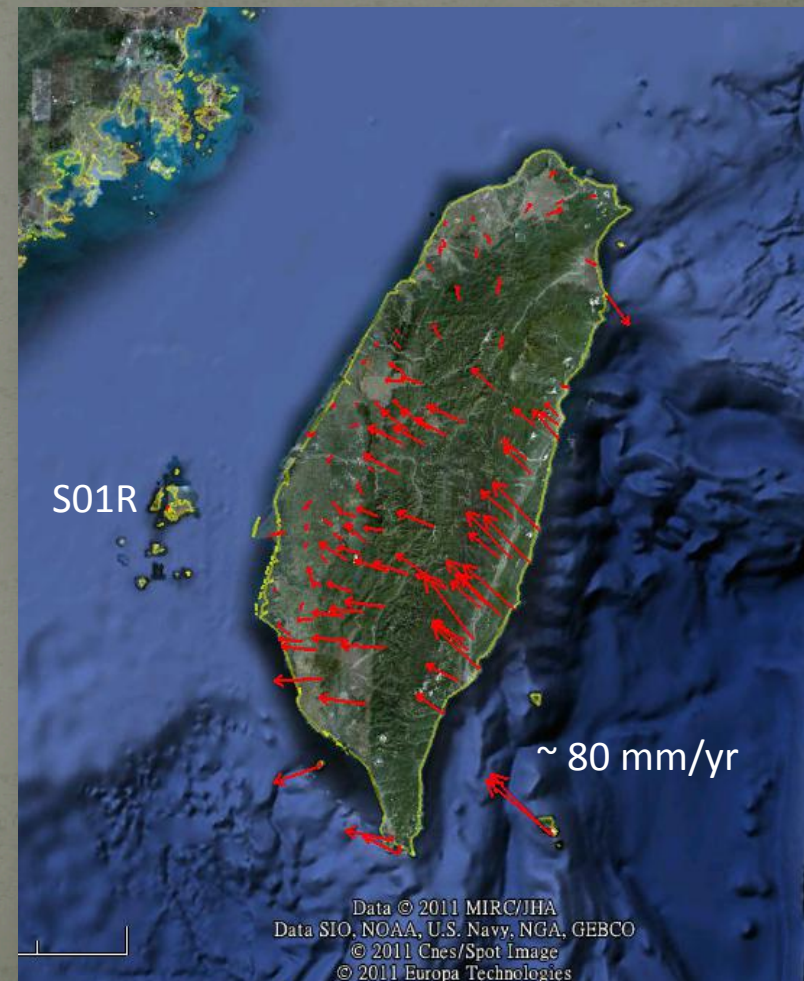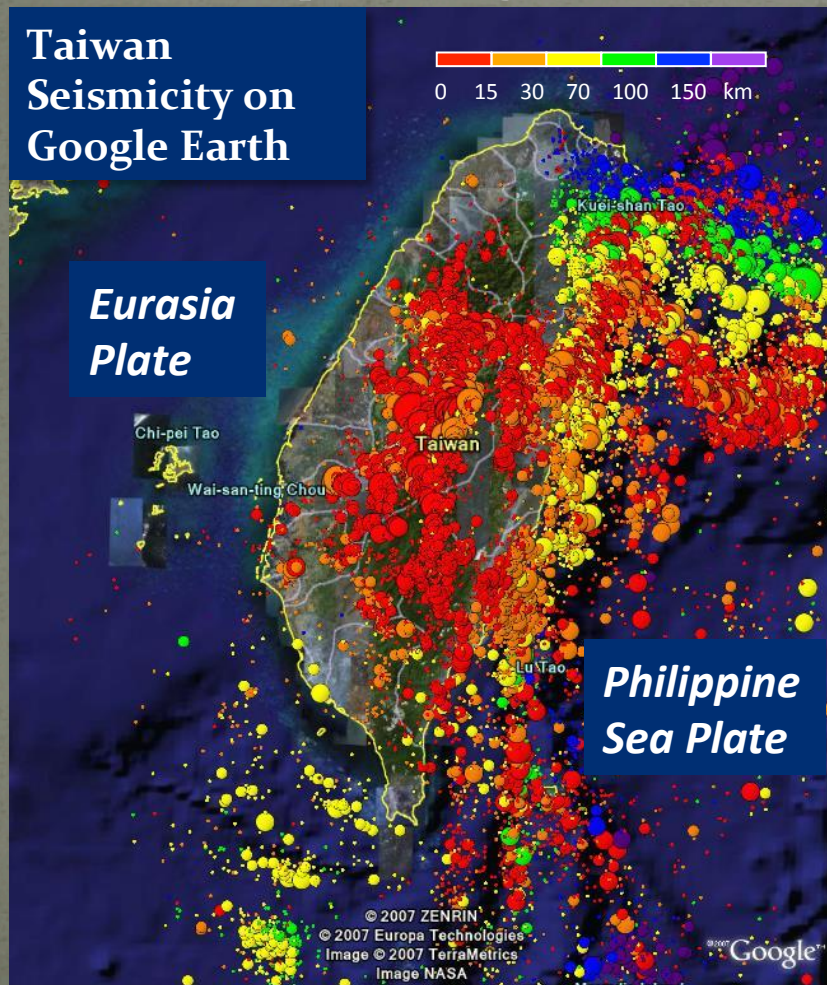- International collaboration

Tectonic Setting
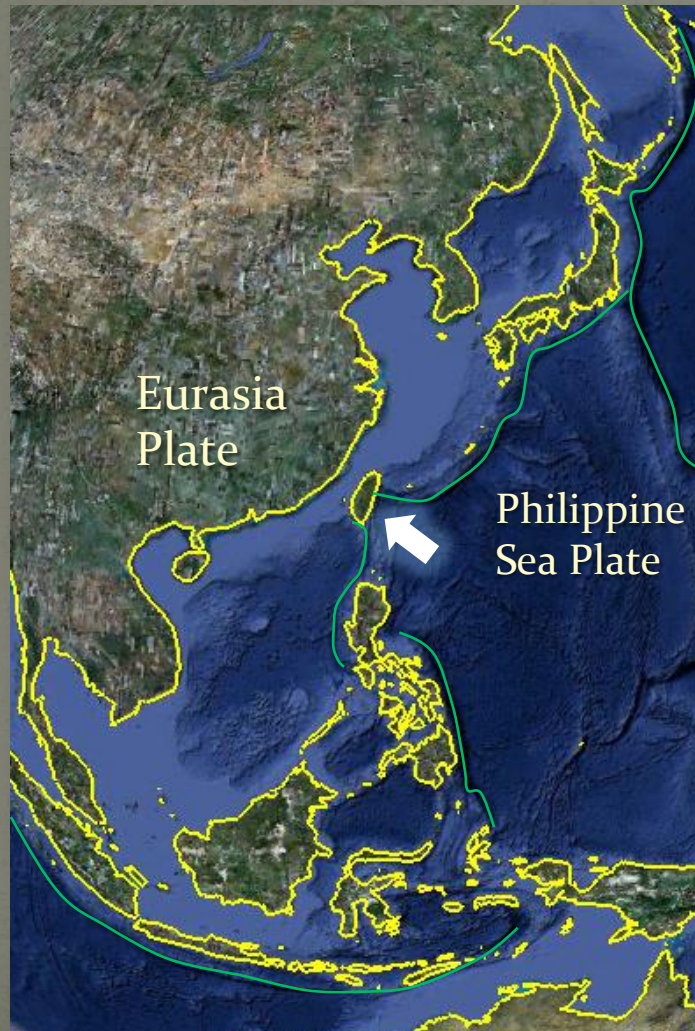
Taiwan is located on the convergent plate boundary zone between the Eurasia and the Philippine Sea plates.
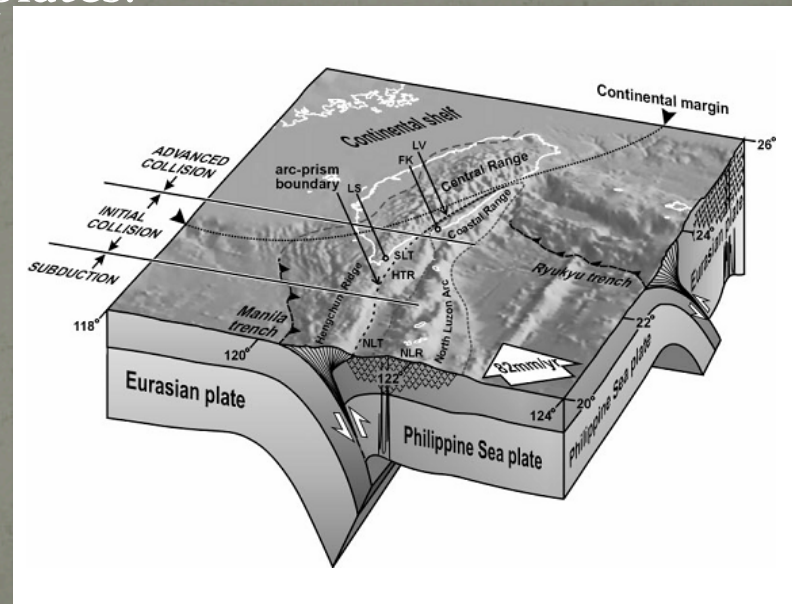
Seismicity and crustal deformation

~50 earthquakes/day

Taiwan Seismicity on Google Earth

Eurasia Plate

Philippine Sea Plate

S01R

~ 80 mm/yr

Monitoring Organizations

- Both the Central Weather Bureau (CWB) and the Institute of Earth Sciences (IES), Academia Sinica have deployed permanent seismic networks to monitor the earthquake activity in the vicinity of Taiwan.

- The CWB is the only authorized organization in Taiwan, who is responsible for rapidly issuing the earthquake information. *(Mission oriented)*

- The IES, Academia Sinica plays as a research institution, who mainly focus on basic scientific topics *(Science oriented)*

CWB Instrumentation

- 1989
  - Merge and upgrade existing seismic stations in Taiwan (TTSN, was initiated by IES)
  - Build up new real-time seismic stations (short-period)
- 1995
  - Build up real-time strong-motion stations
  - TSMIP (~700 sites)
- 2000
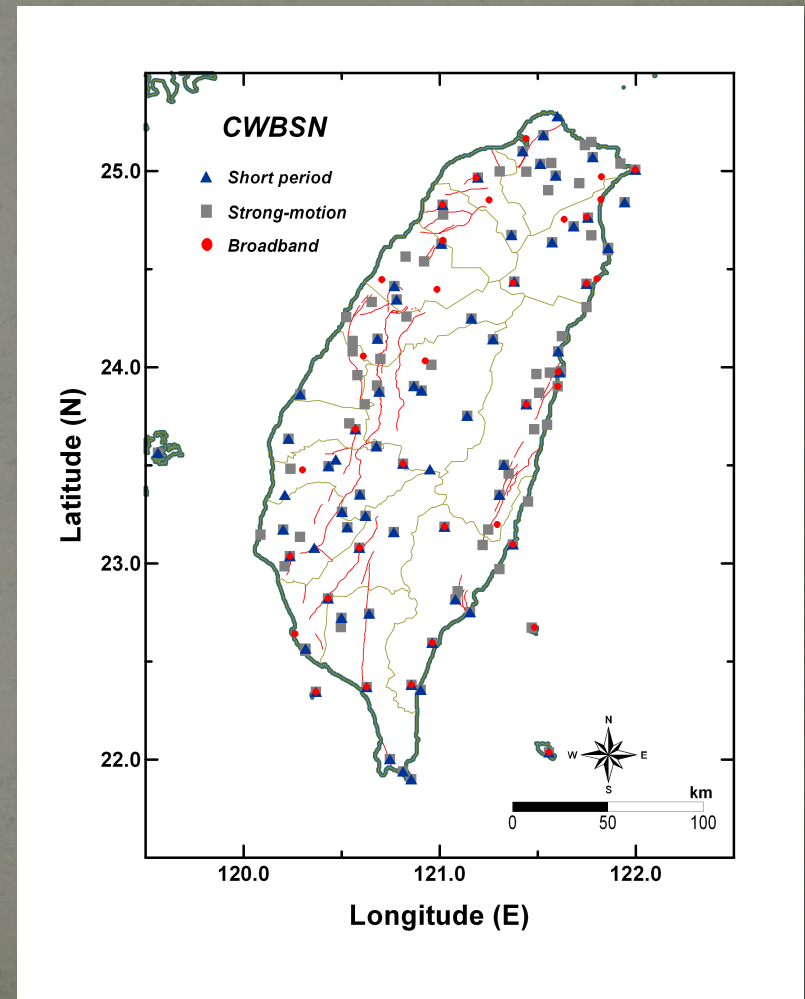 - Build up broadband seismic stations
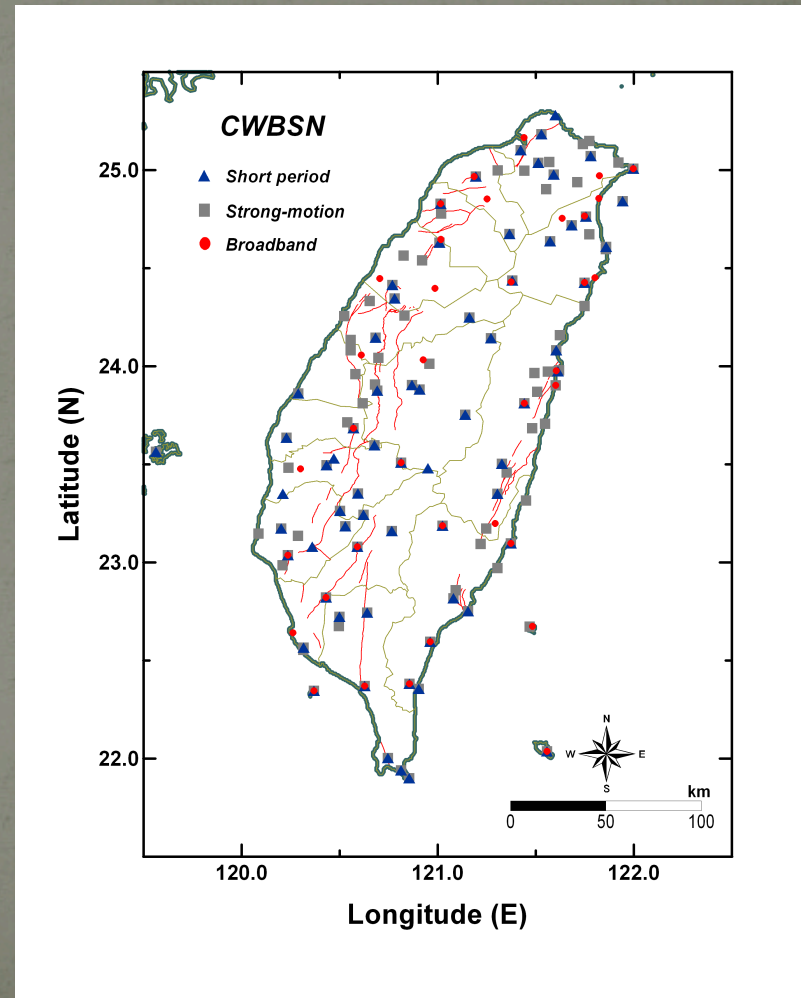
CWBSN

- Earthquake monitoring systems in operation

  - Short-period seismographic system

  - Earthquake rapid reporting system

  - Broadband seismographic system
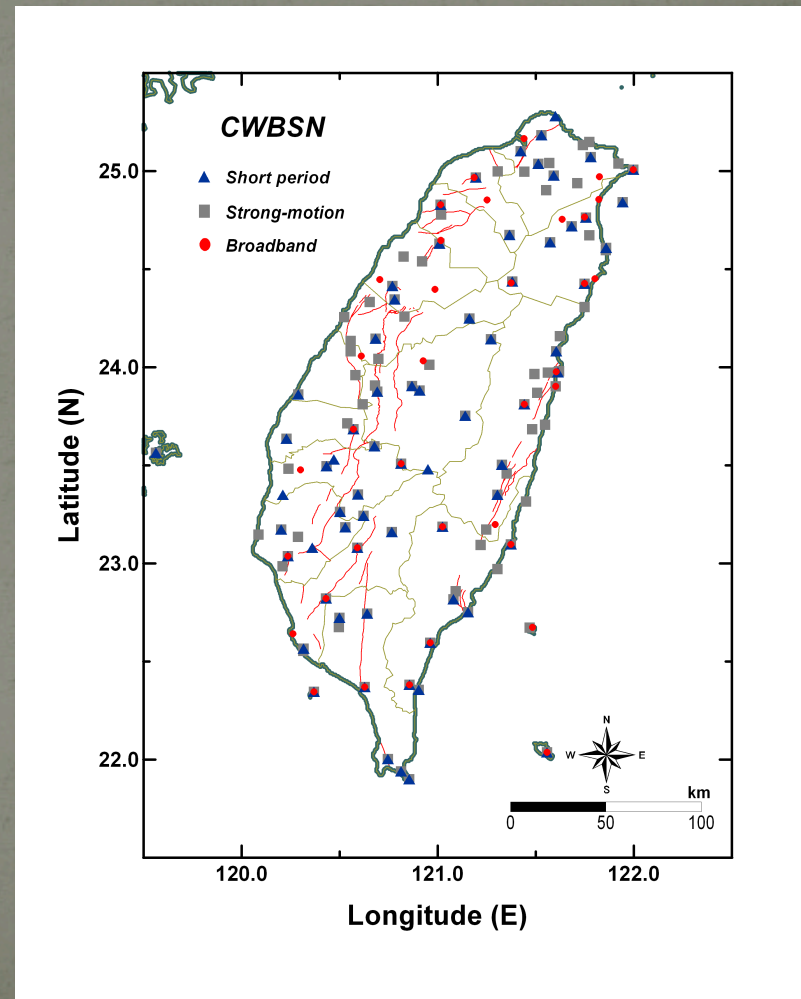
Monitoring System in Operation (I)

- Short-period seismograph system -

  ➢ 71 short-period seismographic stations
  ➢ 12 bits resolution
  ➢ Sampling rate: 100 sps
  ➢ 4.8K dedicated telephone line
  ➢ Continuous recording since 1994
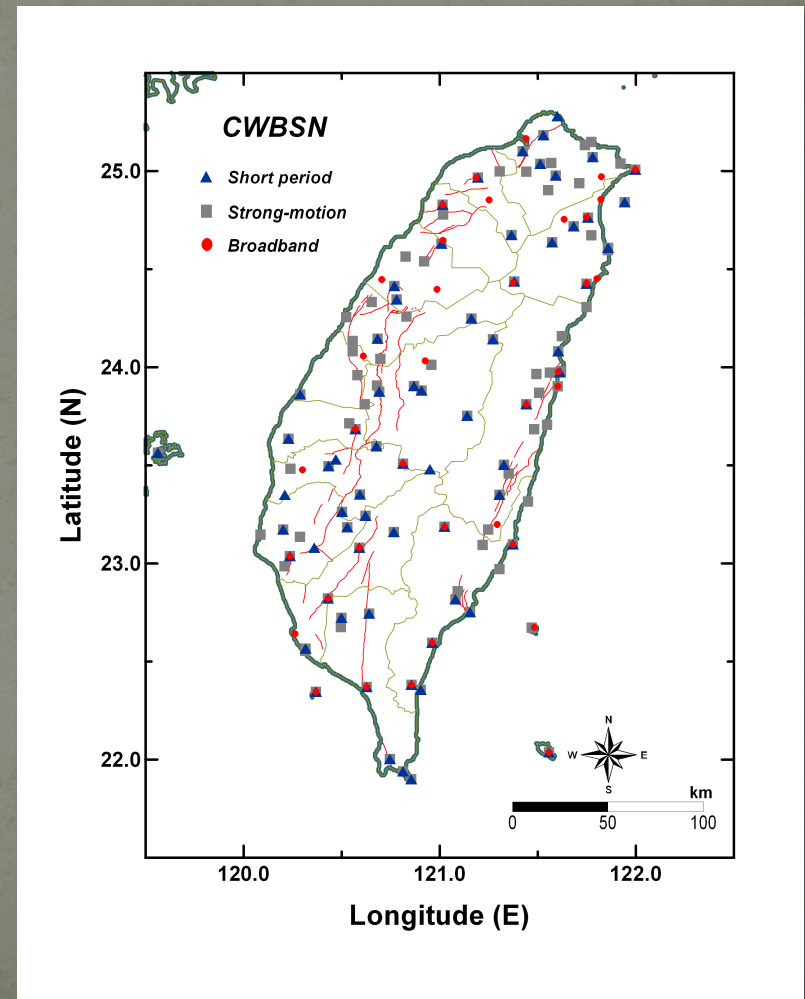 ➢ Earthquake catalog
      - Seismicity observation
      - Tectonic research

- Earthquake rapid reporting system -

  - 102 real-time strong-motion stations
  - 16 bits resolution
  - Sampling rate: 50 sps
  - ± 2g Max. amplitude
  - 4.8K dedicated telephone line
  - Hazard mitigation
    - Rapid notification
    - Early warning

TSMIP: ~700 strong motion stations island-wide

- Broadband seismograph system -

  - 32 broadband seismographic stations
  - 24 bits resolution
  - 0.02-60 sec period range
  - Sampling rate: 100 sps
  - 64K frame-relay network and satellite link
  - Seismological related research
    - Focal mechanism
    - Global earthquake observation

Magnitude of Completeness (Mc)

1973 - 1990 TTSN
1991 - 2008 CWBSN
$LogN = (7.53 \pm 0.06) - (1.01 \pm 0.02)M$
$LogN = (7.45 \pm 0.05) - (0.96 \pm 0.01)M$

Mc 2.4 → 2.0
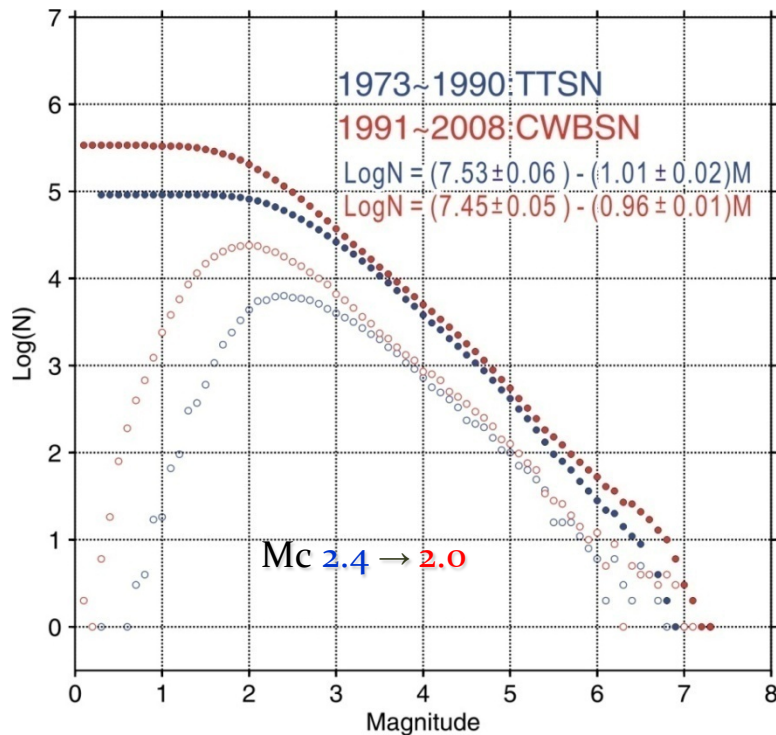
Frequency-Magnitude distribution

IES: Taiwan Telemetered Seismographic Network; TTSN
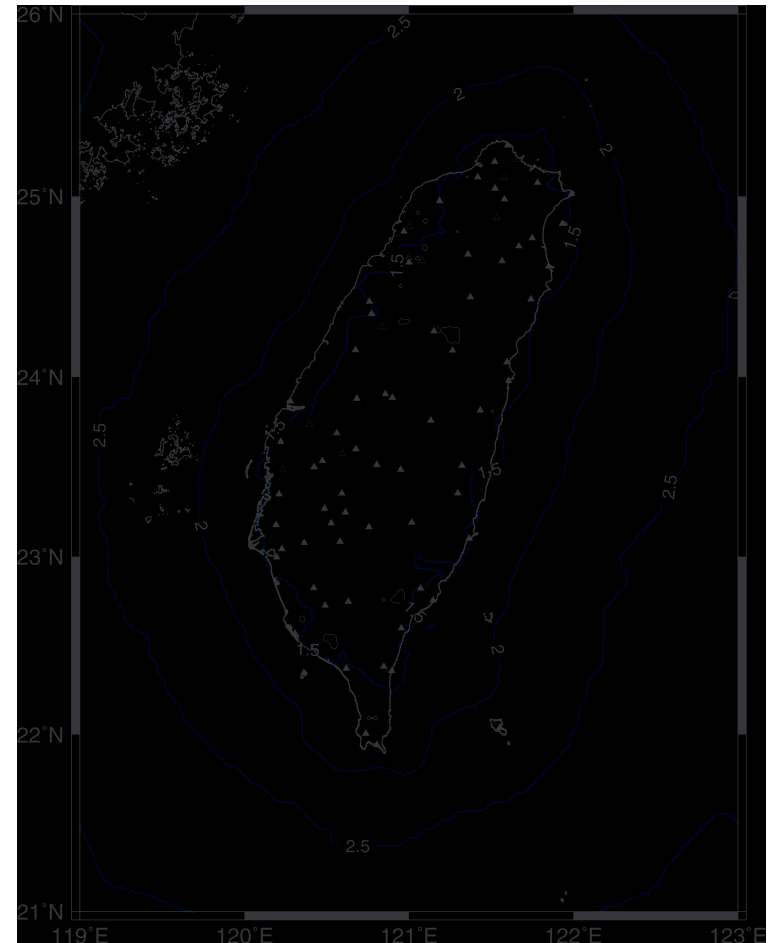
Site :71

Seismicity in Taiwan

Both the event catalog and the seismic waveform data have enabled further studies on ambient tectonics, seismogenic structures, source physics, engineering applications, etc.

Central Weather Bureau
M≥3.5 in 1992-2008
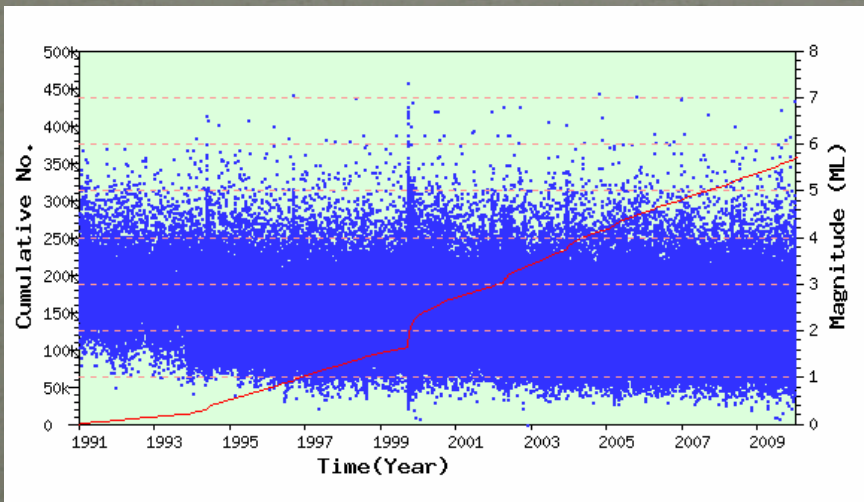
Google Earth 3D viewing
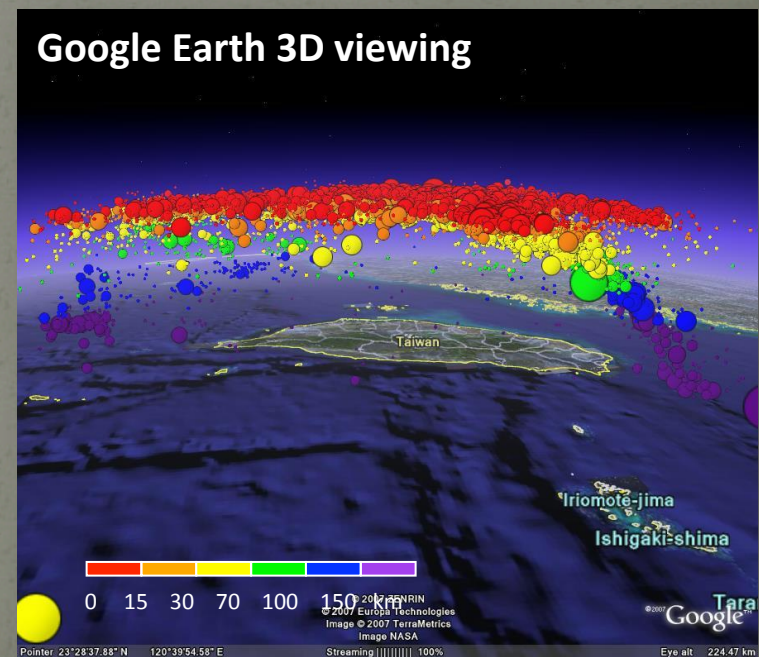
Earthquake Rapid Notification

Virtual Sub-Network for EEW
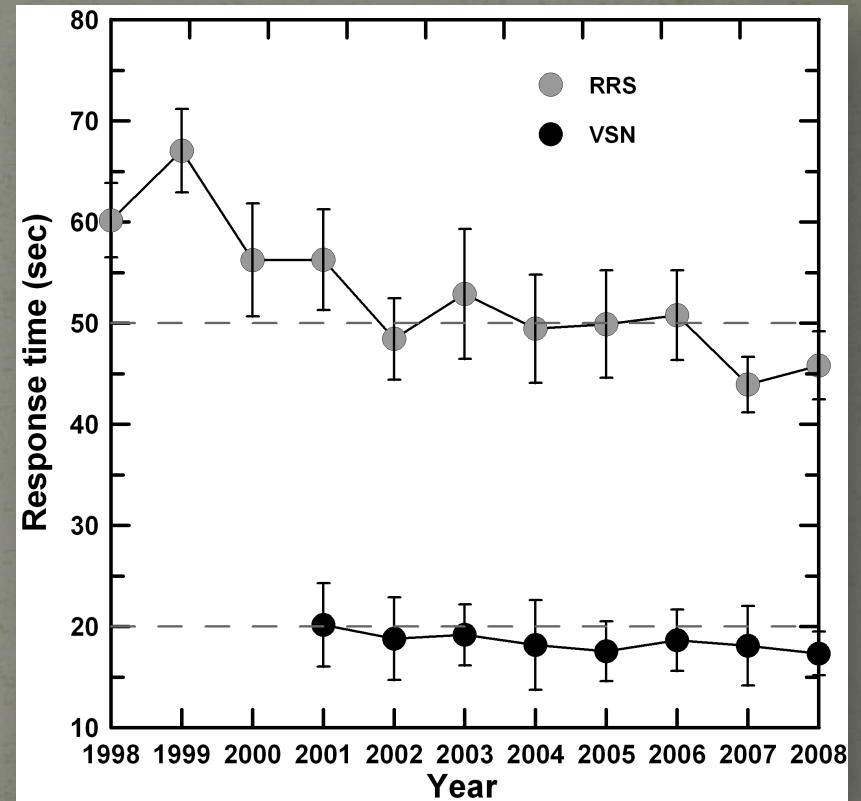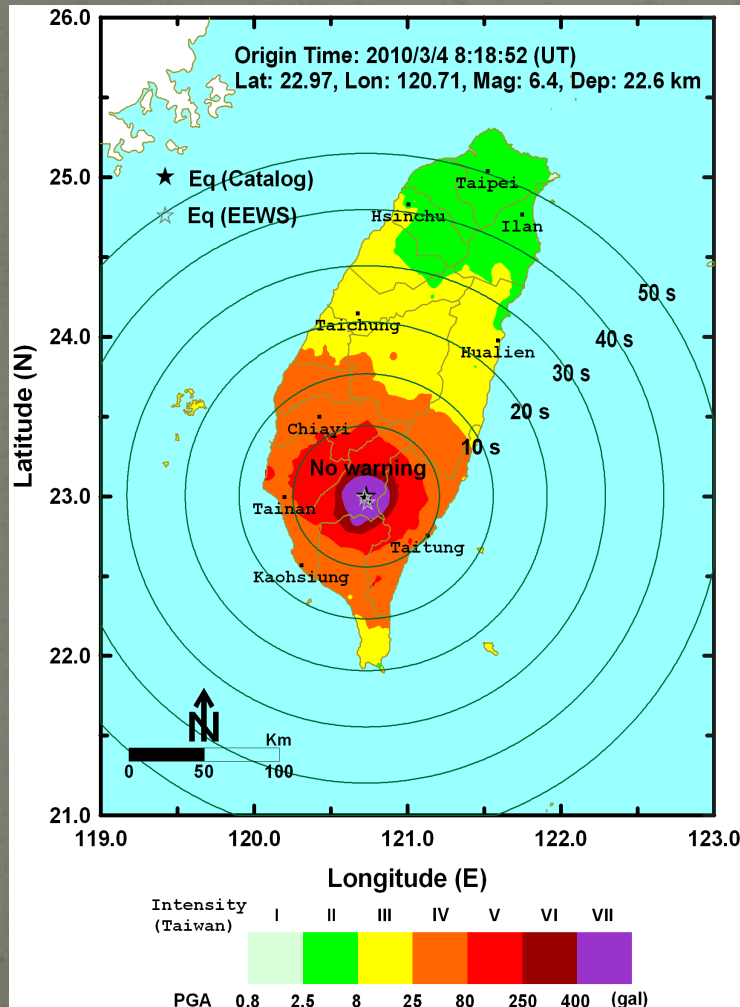
Broadband waveform
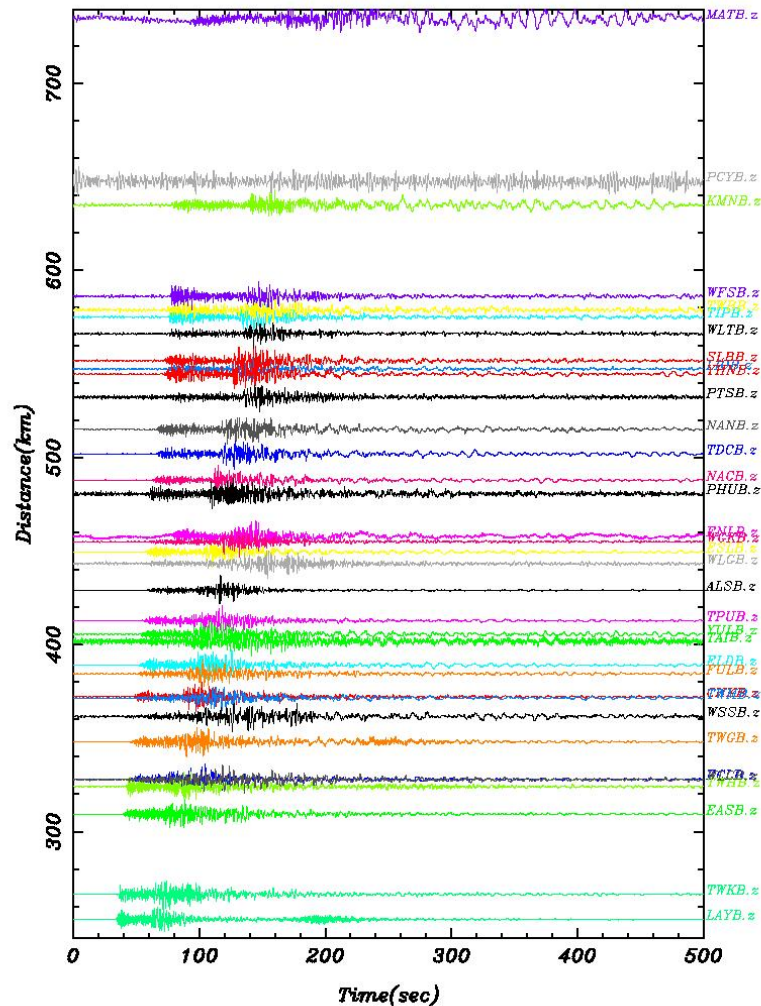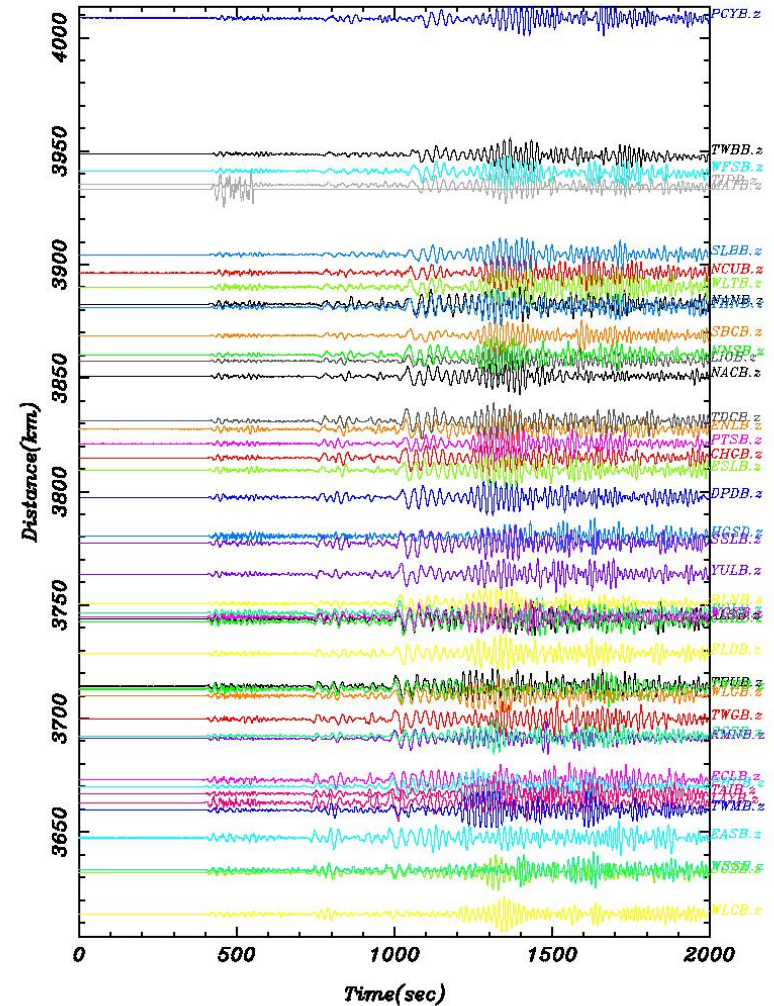
CMT solution

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CWB Early Automatic Report (EAR) :
Origin Time : 2009  4 17 12:37:49.40(UT)
Hypocenter :    23.90 N  121.77 E    48.90 km

CWBSN_BB moment-tensor solution :
 -0.1151350    1.0783101  -0.0646969
  1.0783101   -0.8452970  -1.0453501 x 10+E16 Nt-m
 -0.0646969   -1.0453501   0.9604321
 Centroid depth :   49 km
 Mw :   4.77
 Average MISFIT : 0.561   ( The fit is good     )

Best double couple solutions :
nodal plane(1) strike/dip/slip: 248/ 39/ 145
nodal plane(2) strike/dip/slip:   7/ 69/  57


         --------####
        -------------#######
       ----------------#########
     -----------########-------####
    --------############---------#
   ------###############-----------
 -----###################------------
 ---#####################-----------  -
 --#######################------------  -
 --########    #########--------------
 -######## T #########-------   ---
  ########    ########-------- P --
   ################---------    -
    ##############------------
      ##########----------
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```
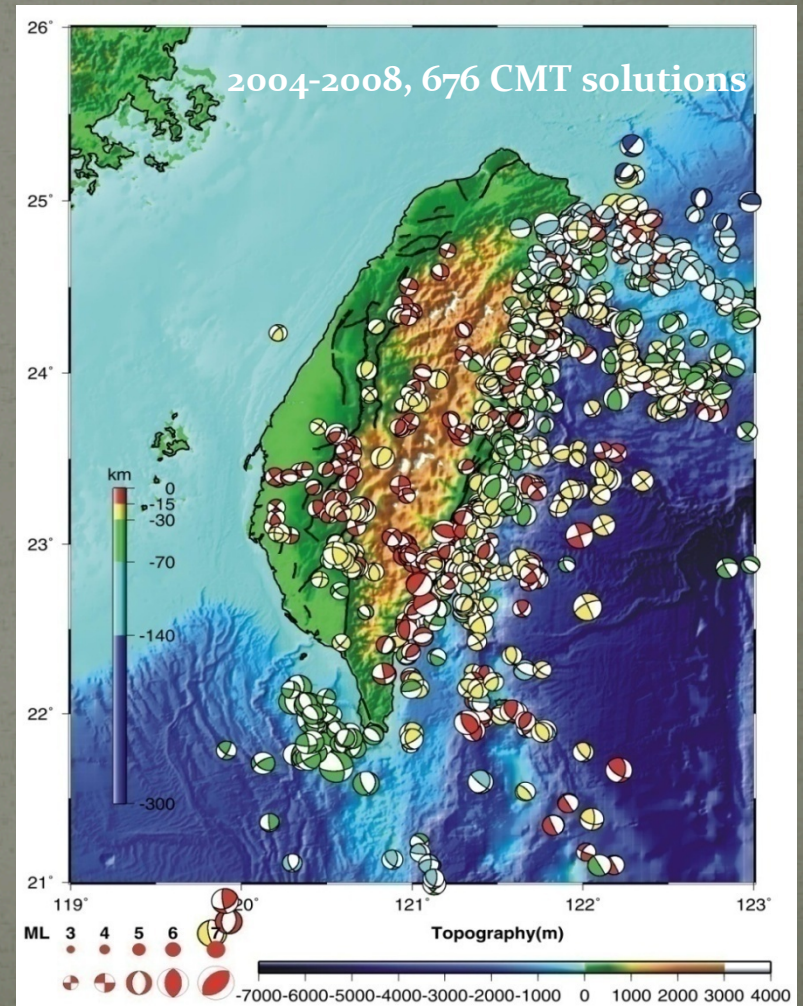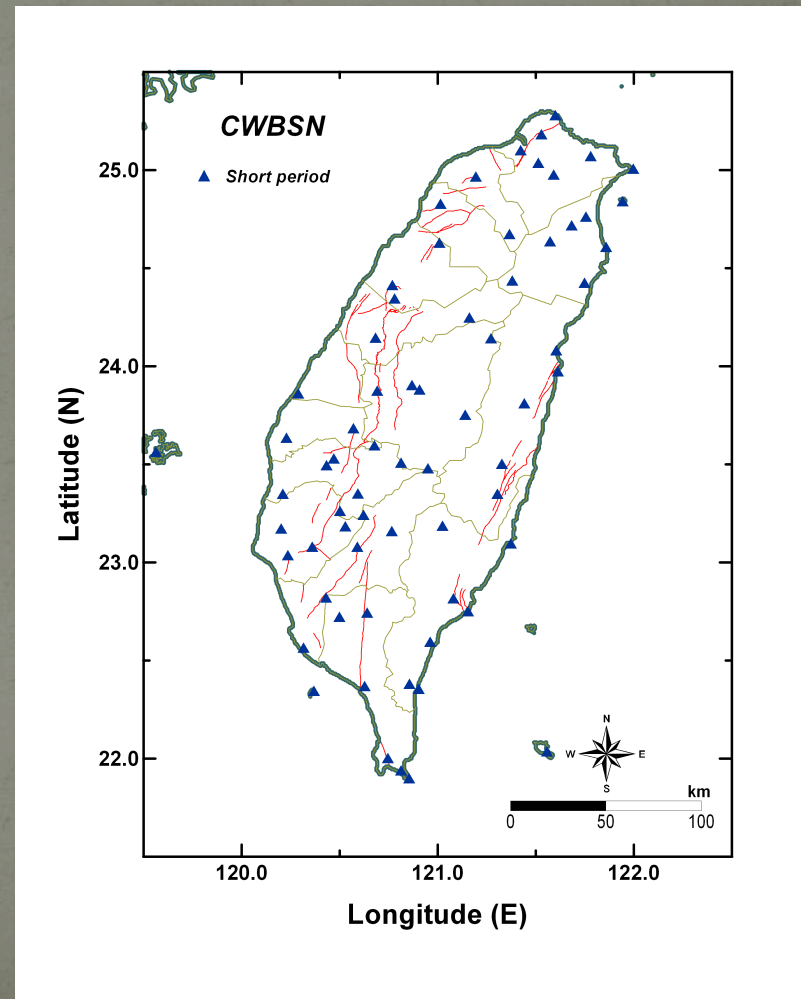

2004-2008, 676 CMT solutions

CWBSN Improvement

- Upgrading seismic stations with state-of-art instruments

- Increase the dynamic range up to 24-bits and raise the sampling rate to 100 sps

- Using the IP network for data transmission

- Combine short-period, strong-motion and broadband data into multi-channel observations

- >70 sites have been upgraded

Borehole Stations

- The next generation seismic station in Taiwan

- Borehole depth is set to 300 m

- 3 seismic sensors are deployed at one site: 1 borehole BB sensor, 1 borehole FBA sensor, and 1 surface FBA sensor

- 14 stations have been established

- Plan to build 8 stations per year for the following 5 years
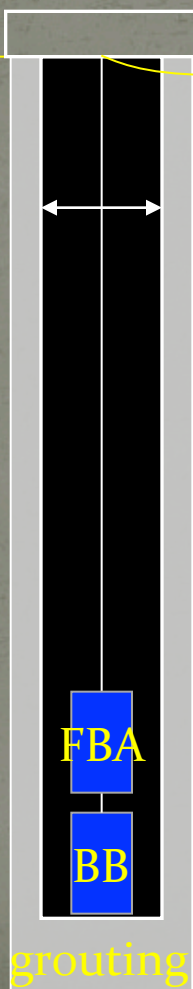
Borehole Stations

DAU

Frame Relay

FBA
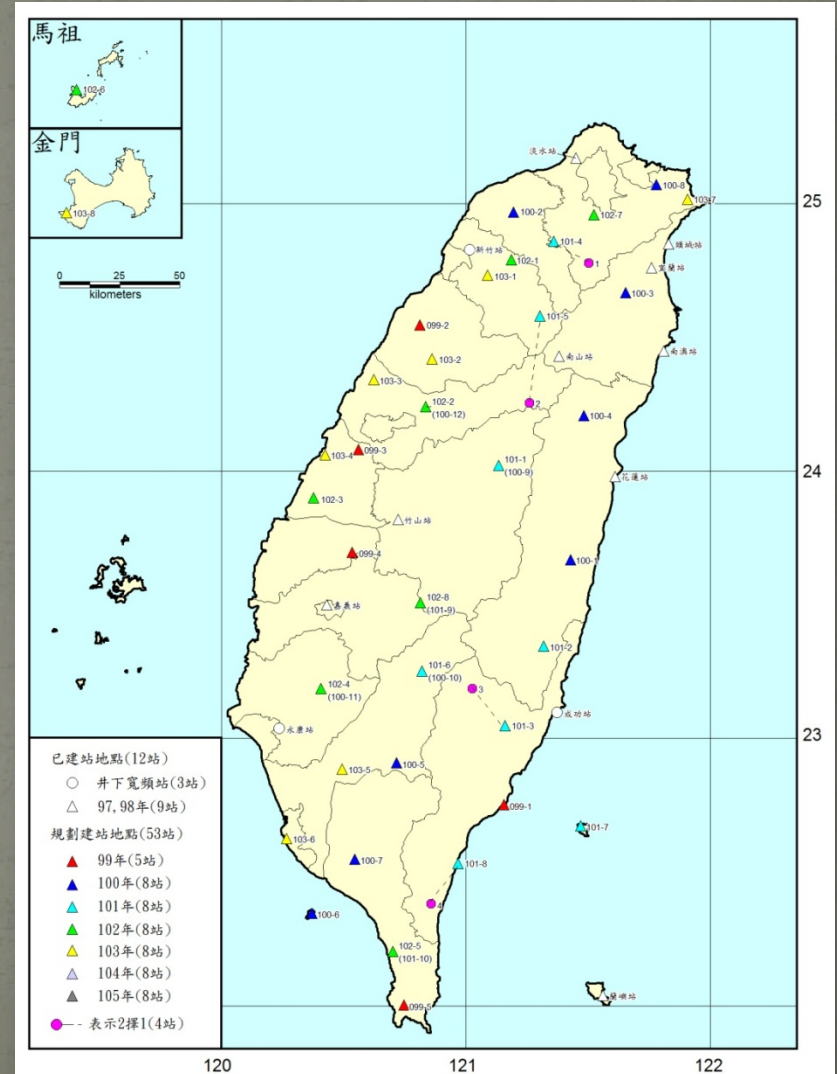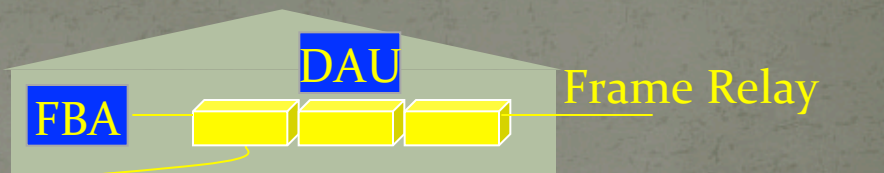
SMART-24R

PA-23

Diameter 5 inch

300m

KS-2000BH

PA-23BH

FBA

BB

18m

grouting

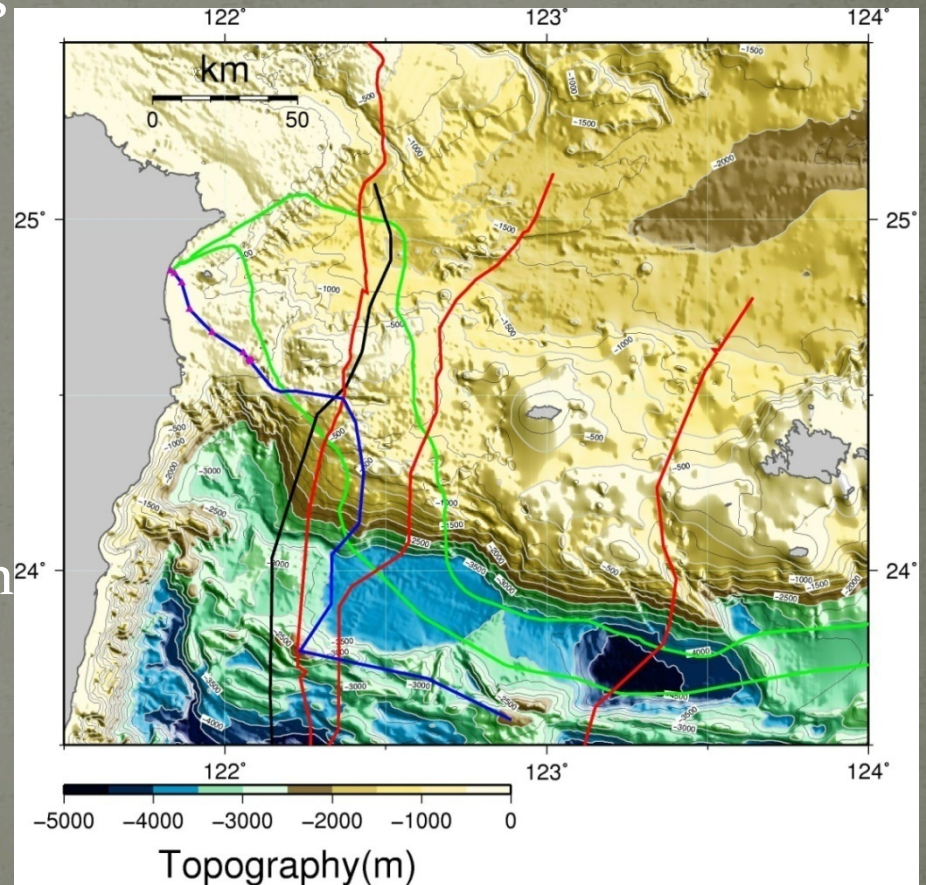Specification
Well type：dry
Well material：anti-rust steel
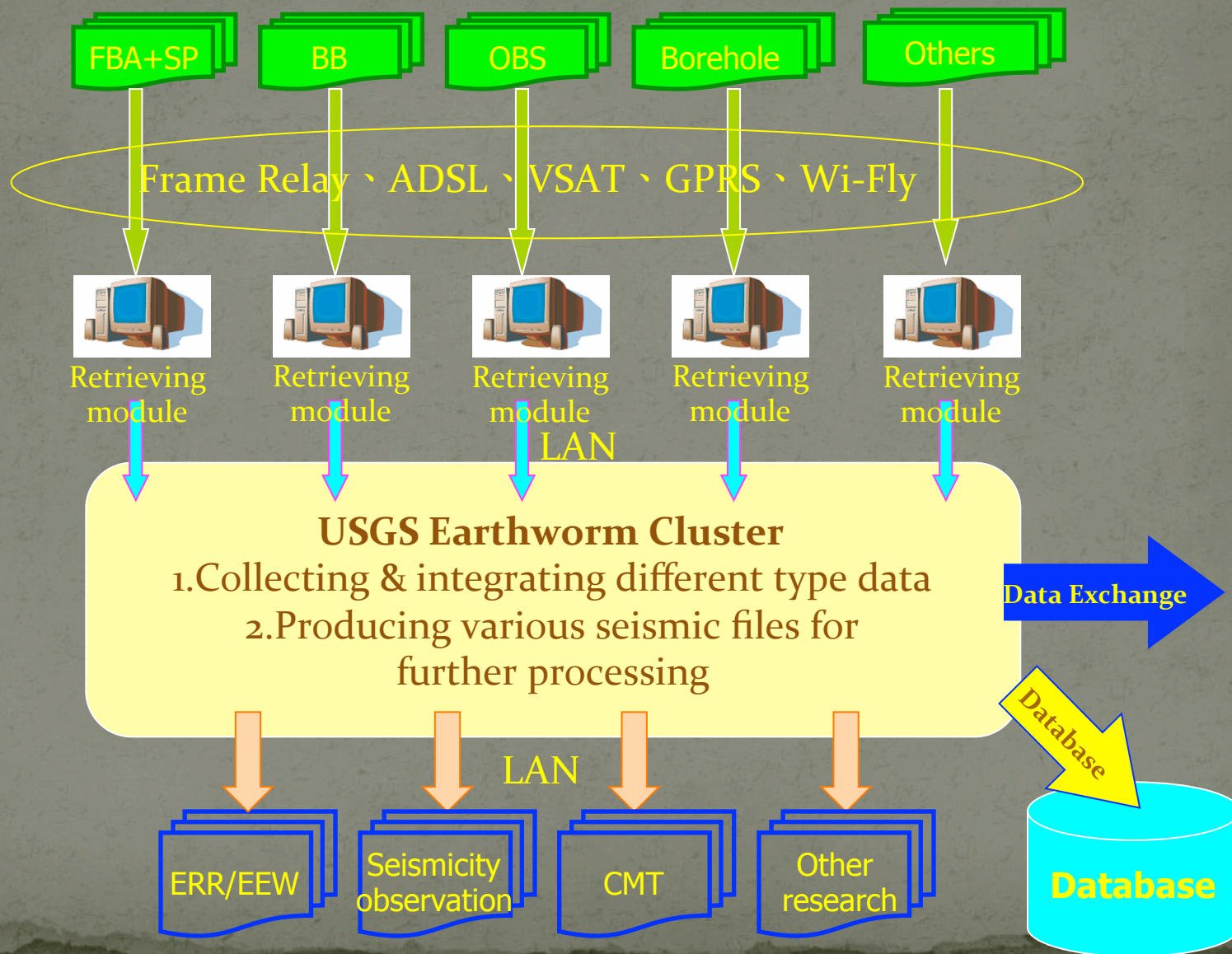Drilling depth：318 m
Well length：300 m

Cable OBS stations

- To better monitor earthquakes occurred offshore E. Taiwan

- Lay the fiber cable from Toucheng

- Cable length is about 45 km, and the Max. ocean bottom depth is about 300 m

- 1 BB sensor and 1 FBA sensor in 2011

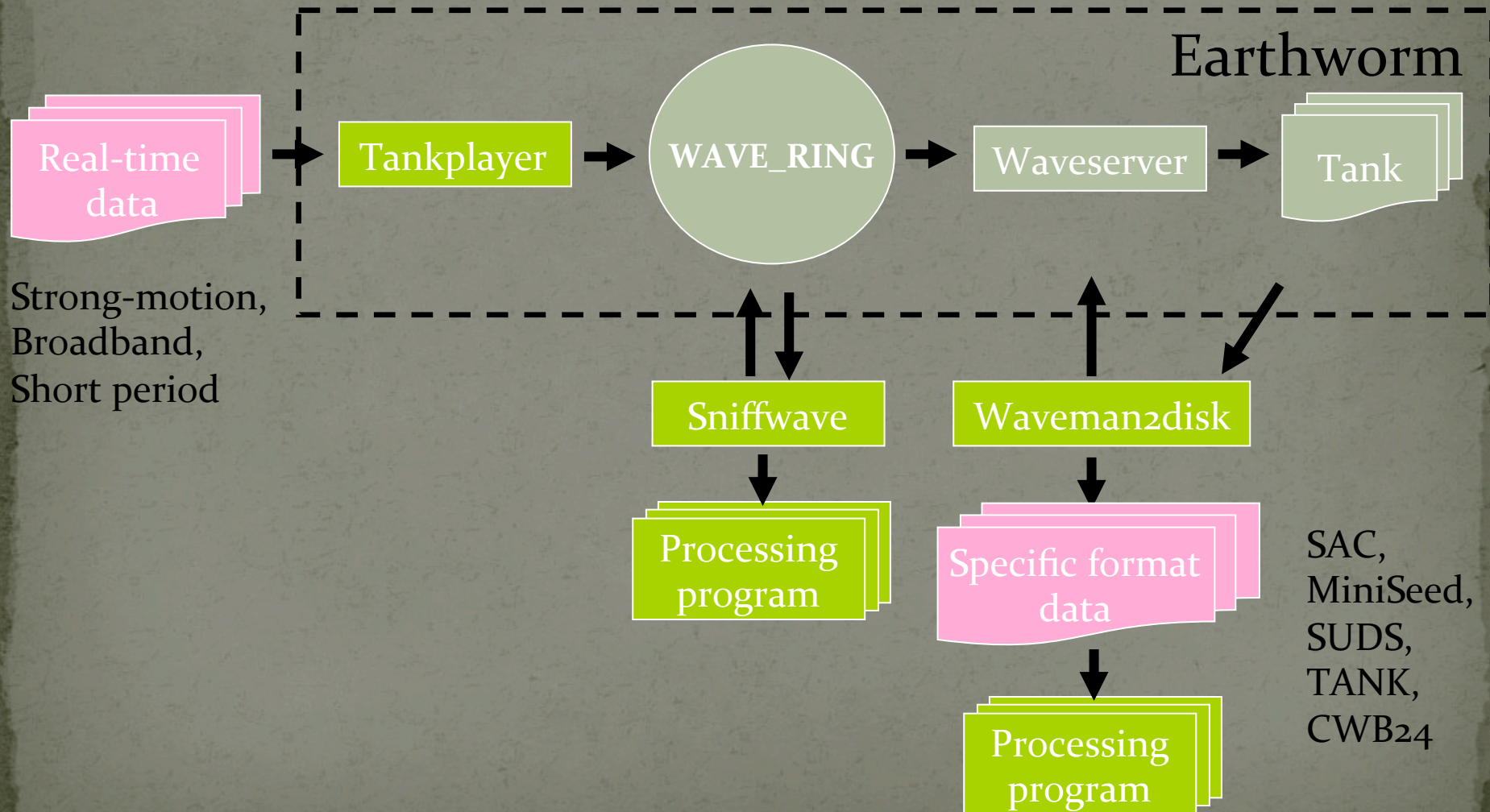- Extend the cable length and add more OBS in the future

Topography(m)

Integrated Data Processing Platform

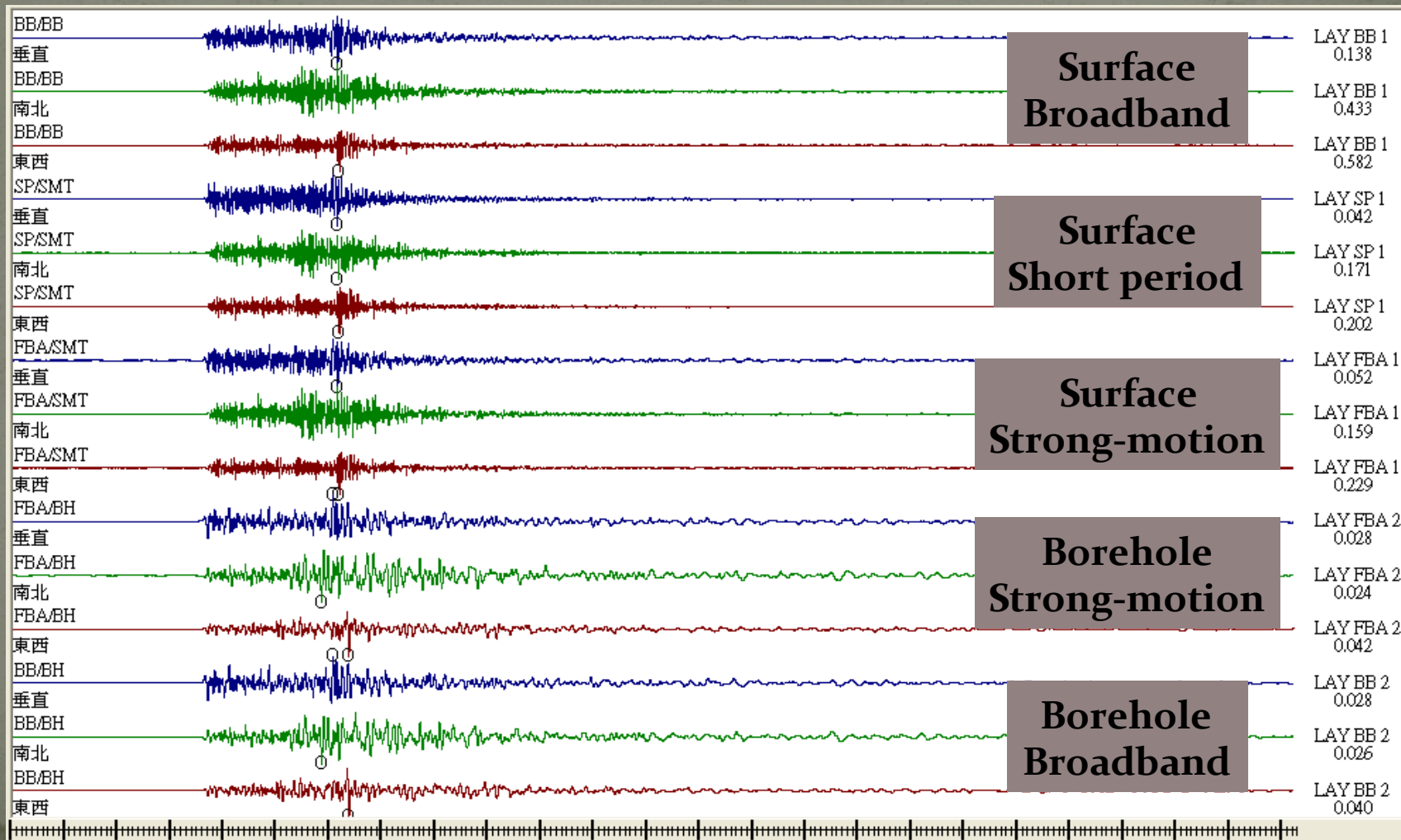FBA+SP　　BB　　OBS　　Borehole　　Others

Frame Relay、ADSL、VSAT、GPRS、Wi-Fly

Retrieving module　　Retrieving module　　Retrieving module　　Retrieving module　　Retrieving module

LAN

USGS Earthworm Cluster
1.Collecting & integrating different type data
2.Producing various seismic files for further processing

Data Exchange

Database

LAN

ERR/EEW　　Seismicity observation　　CMT　　Other research

Database

Real-Time Data Integration

Multi-Channel Waveform

2010/3/4 16:16:16 M$_L$ 5.7   **Lanyu station**

CWB Summary

- Currently, the CWBSN is composed of 3 seismic monitoring systems:
  - Short-period
  - Earthquake rapid reporting system (strong-motion)
  - Broadband
- New progressive instrumental projects are proposed for establishing the next generation of seismographic network in Taiwan,
  - Instruments improvement of CWBSN
  - Build up borehole seismographic stations
  - Build up cable-based OBS stations
- Earthworm clusters are utilized to merge all the real-time data

Taiwan Seismicity

Taiwan Seismicity on Google Earth

Eurasia Plate

Philippine Sea Plate
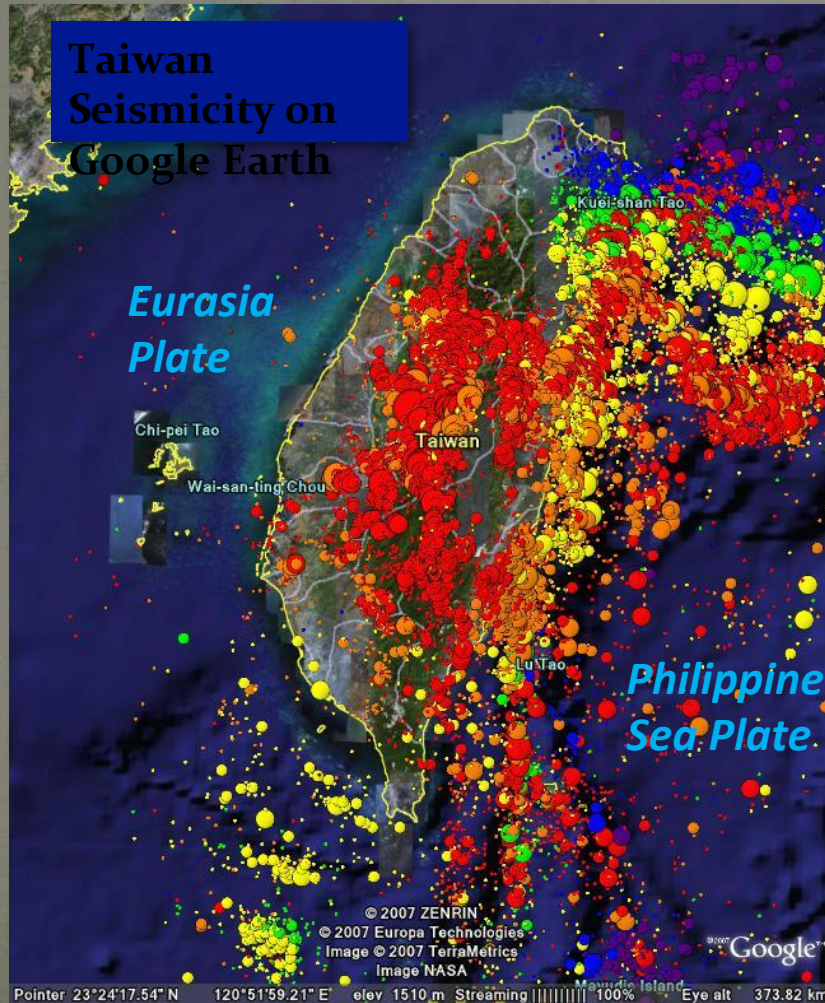
Data Source:

Central Weather Bureau

M≥3.5 in 1992-2008

0   15   30   70   100   150   km
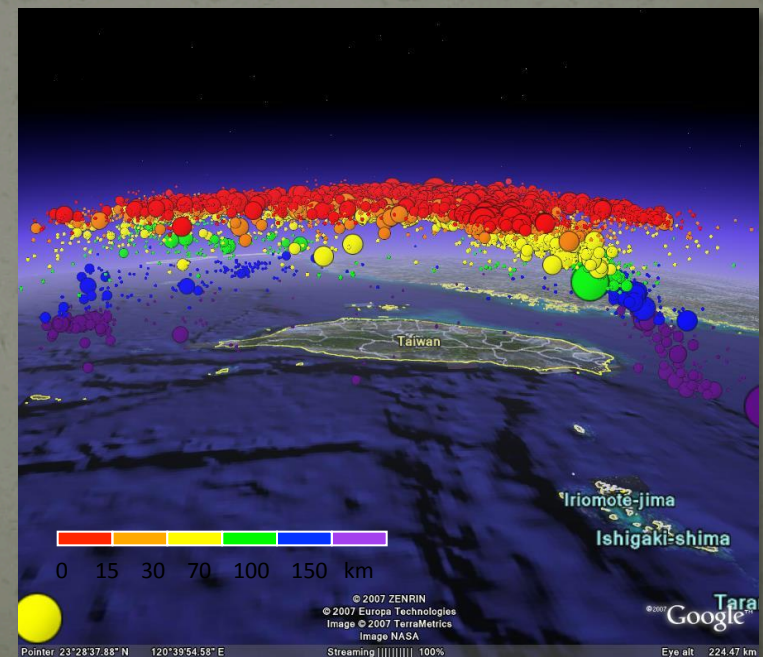
Statistics of Taiwan Seismicity
CWB Event Catalog: *1999/11/01~20091031*
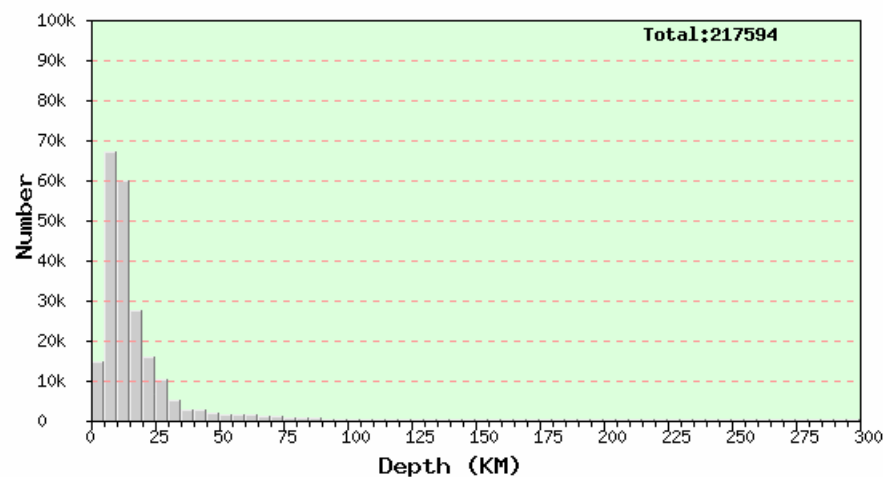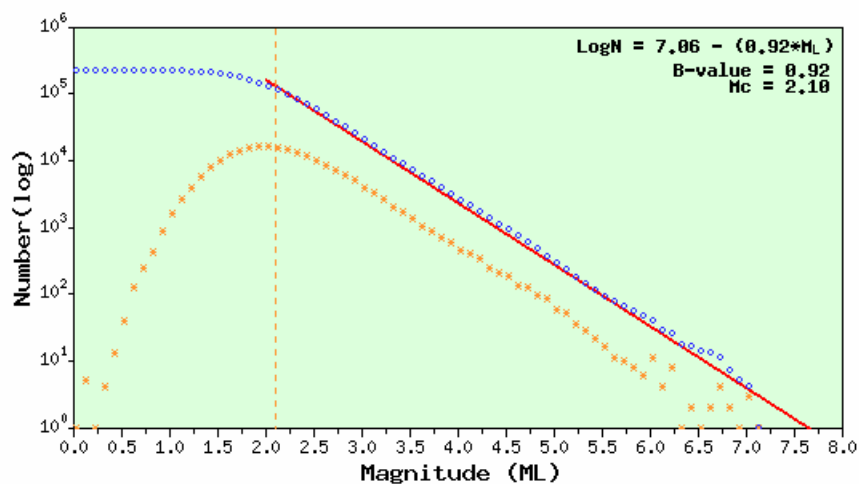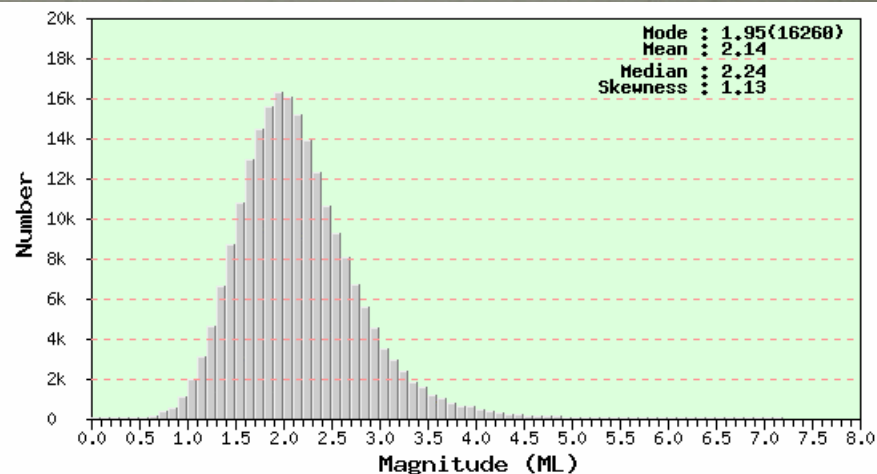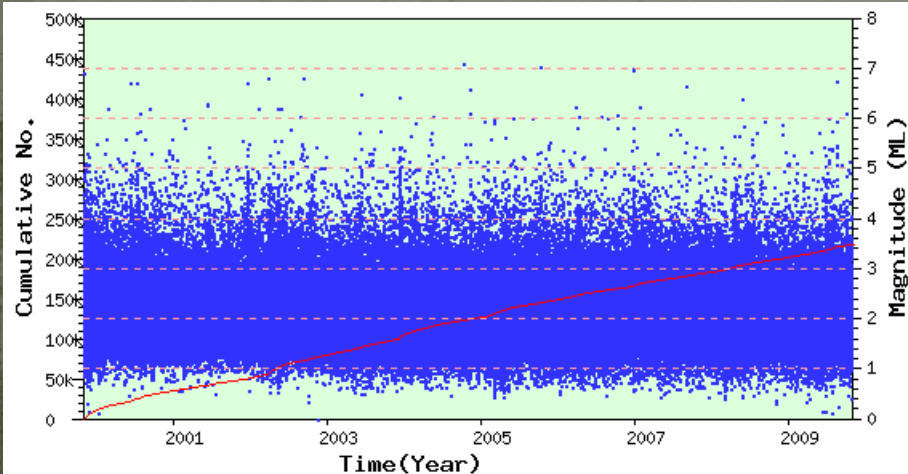
Date : 19991101 00:00:00 ~ 20091031 23:59:59

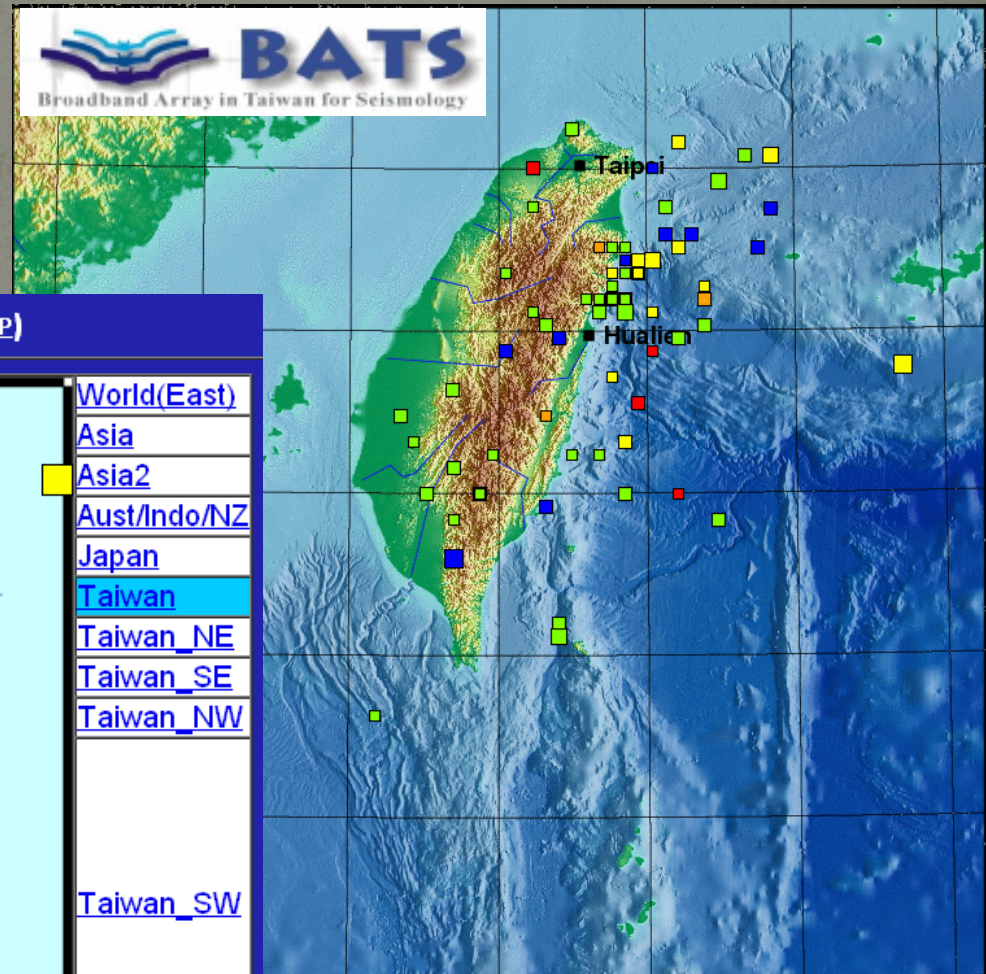# Broadband Array in Taiwan for Seismology (**BATS**)

Data Management Center, Institute of Earth Sciences, Academia Sinica
http://dmc.earth.sinica.edu.tw   http://bats.earth.sinica.edu.tw
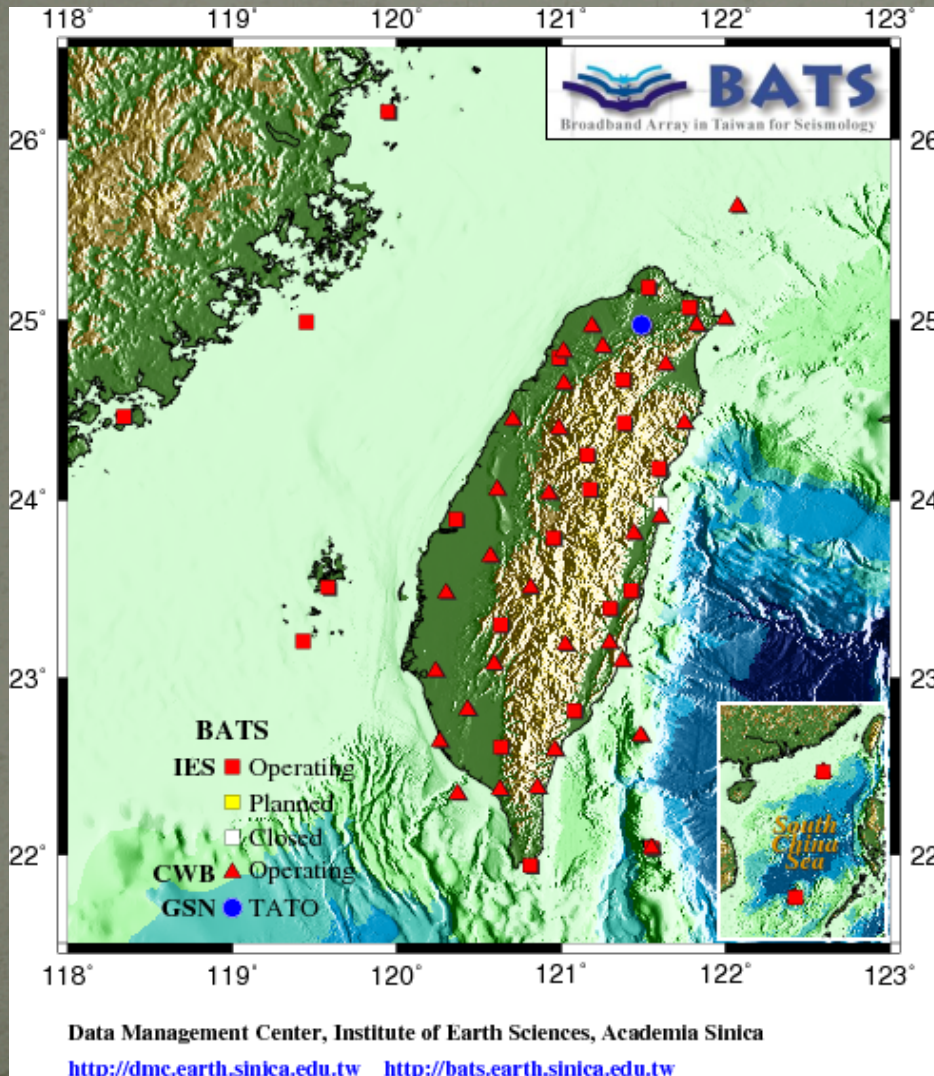
Broadband **A**rray in **T**aiwan for **S**eismology

IES:	25
CWB:	34
GSN:	1
	59

◆ **To better monitor Taiwan earthquakes**
◆ **Provide high quality waveform data**

Taiwan Earthquake Monitoring
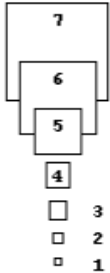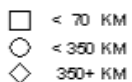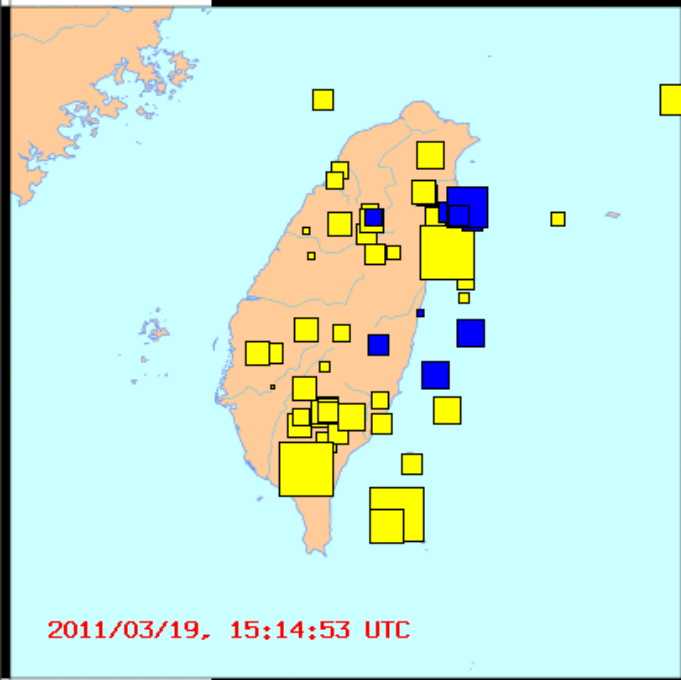
Near Real-time Source Inversion
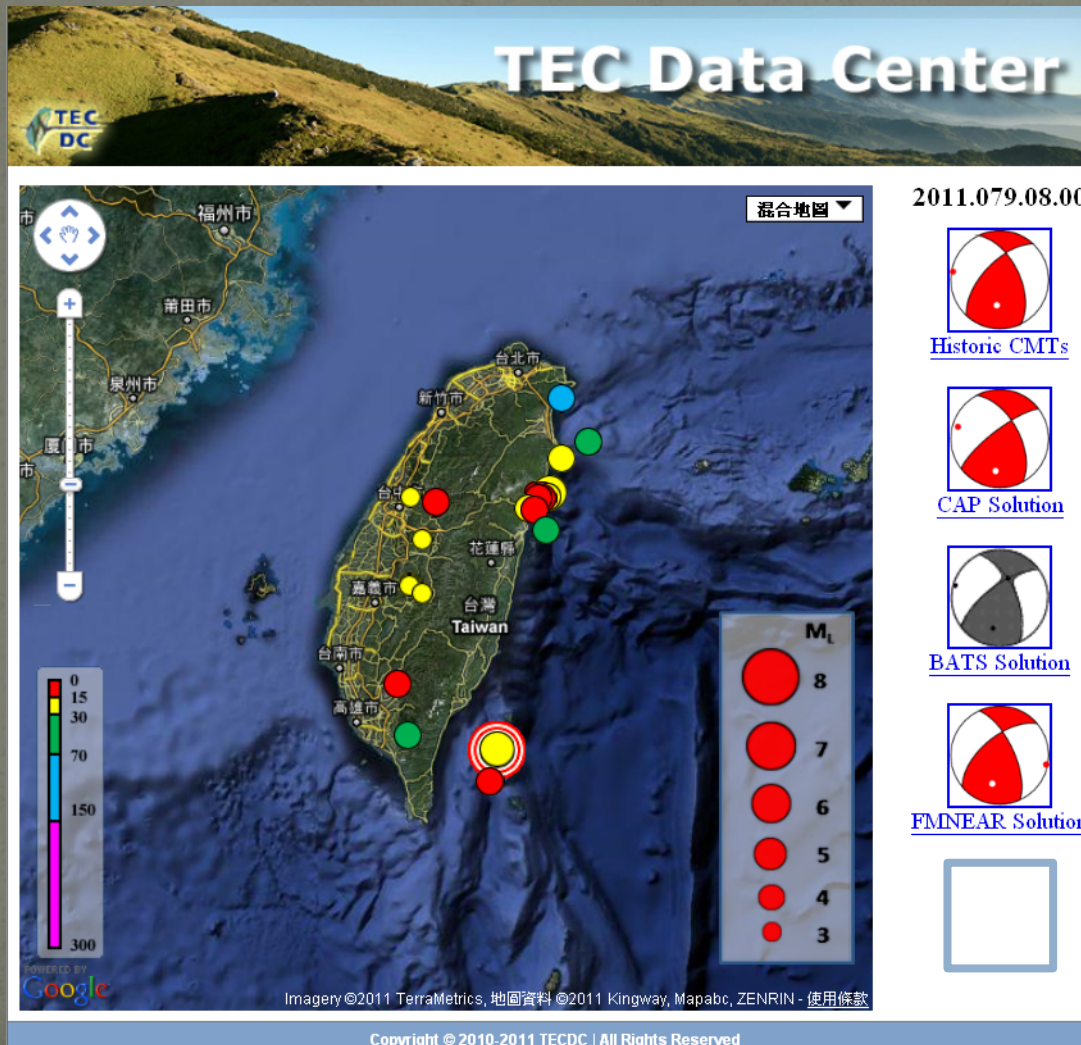
Source Inversion Methods:

- Nearby Historical BATS CMT Solutions (< 5 sec)

- Real-time CAP Solution (~2 min.)

- Routine BATS CMT Solution (<30 min.)

- FMNEAR Solution (<10 min.)

- W-Phase Inversion (M>6) (<20 min.)

GCMT Solution

Necessity to a Wider Regional Network
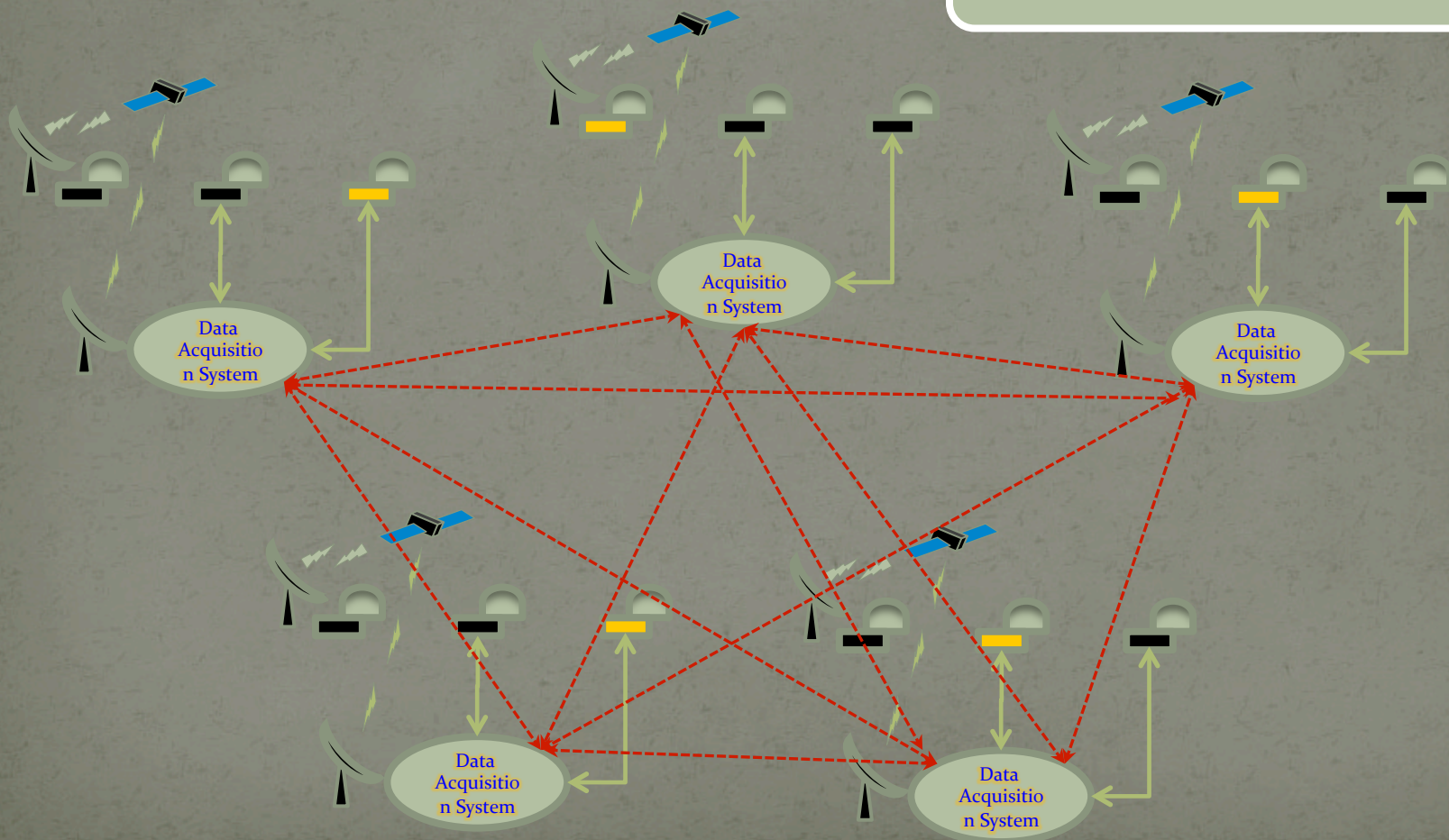
Earthquake Off Pacific Asia Could Generate Strong Tsunami

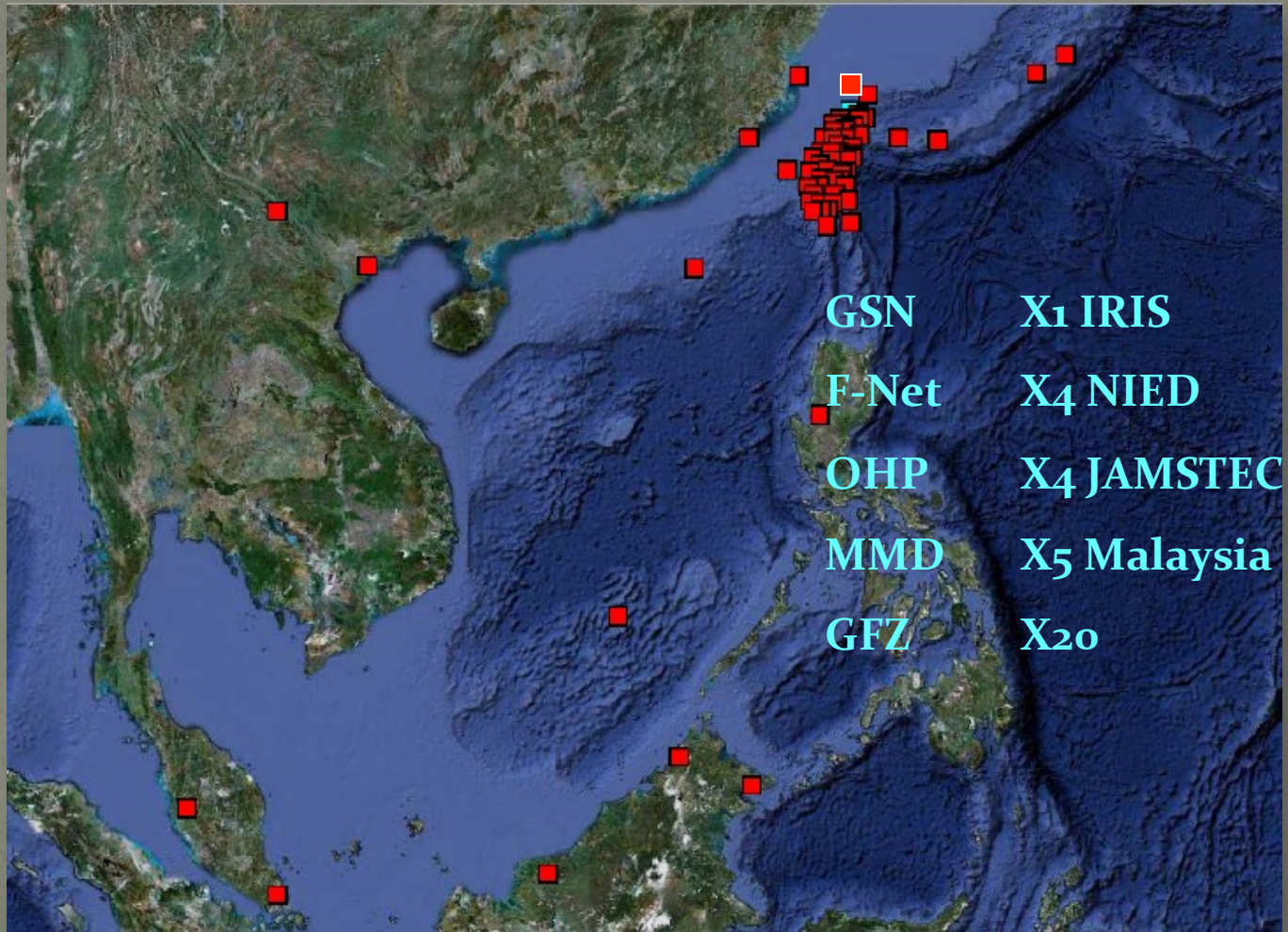The Japan-Taiwan geodynamic system is very similar to the Indonesian-Tibet one.

Hsu and Sibuet, 2005
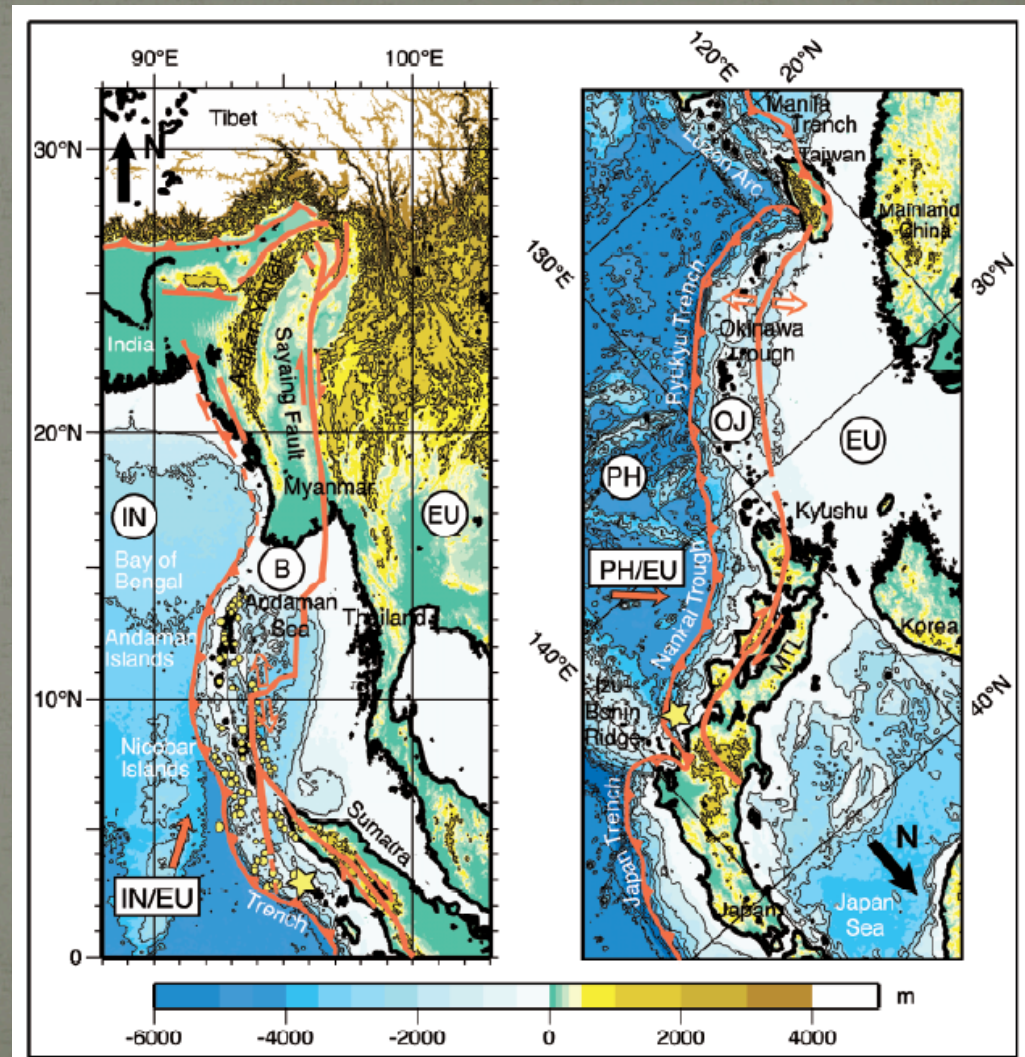
Global Earthquake Monitoring

Increasing the aperture of individual network

Data Exchange among DCs

GSN   X1 IRIS

F-Net   X4 NIED

OHP   X4 JAMSTEC

MMD   X5 Malaysia

GFZ   X20

South China Sea Virtual Network
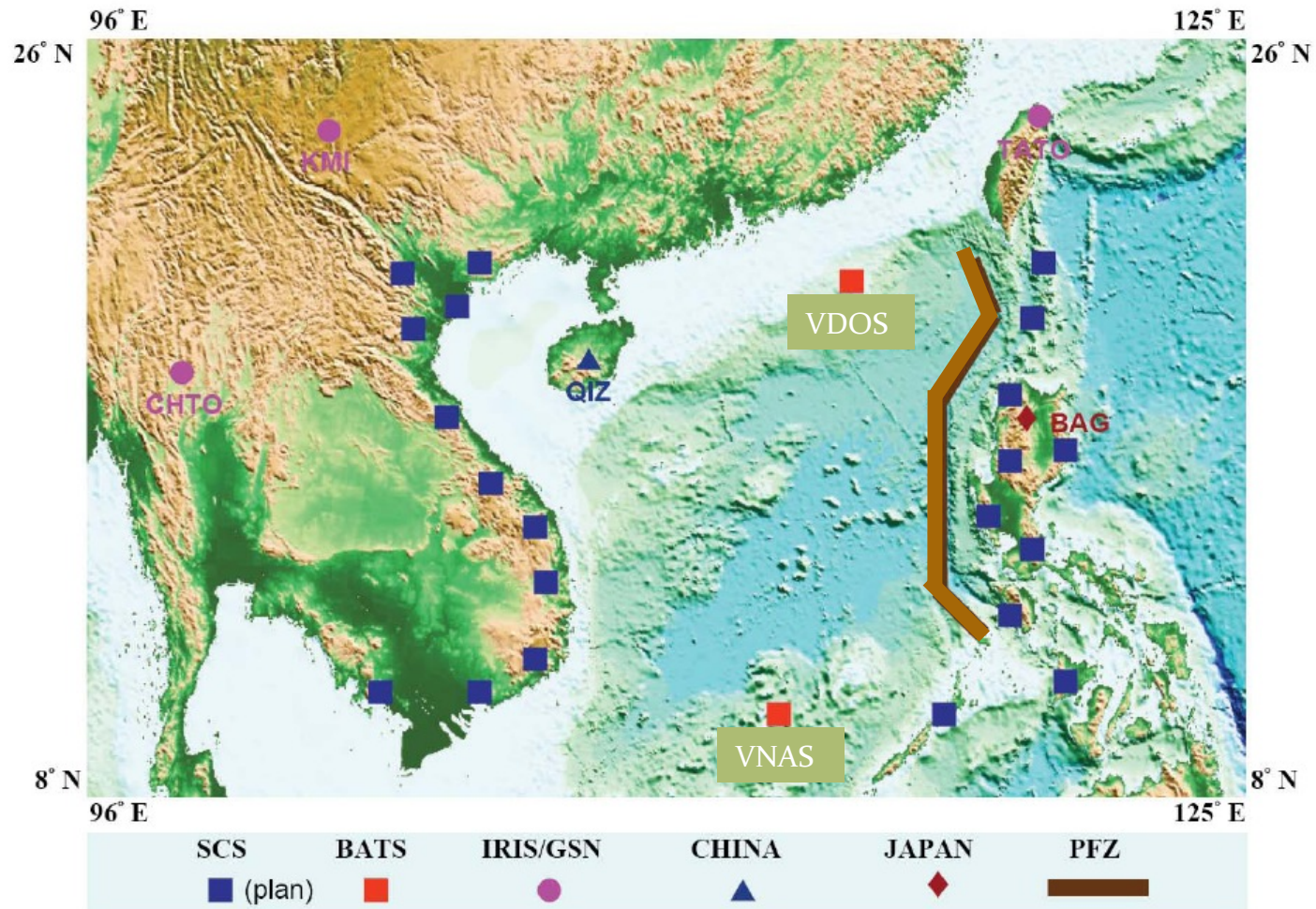
Global/Regional Earthquake Monitoring
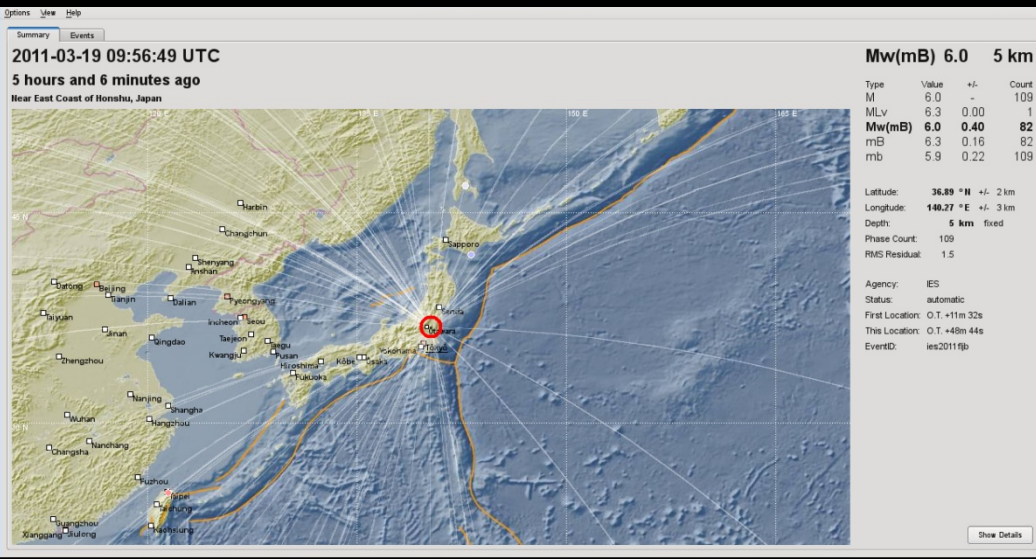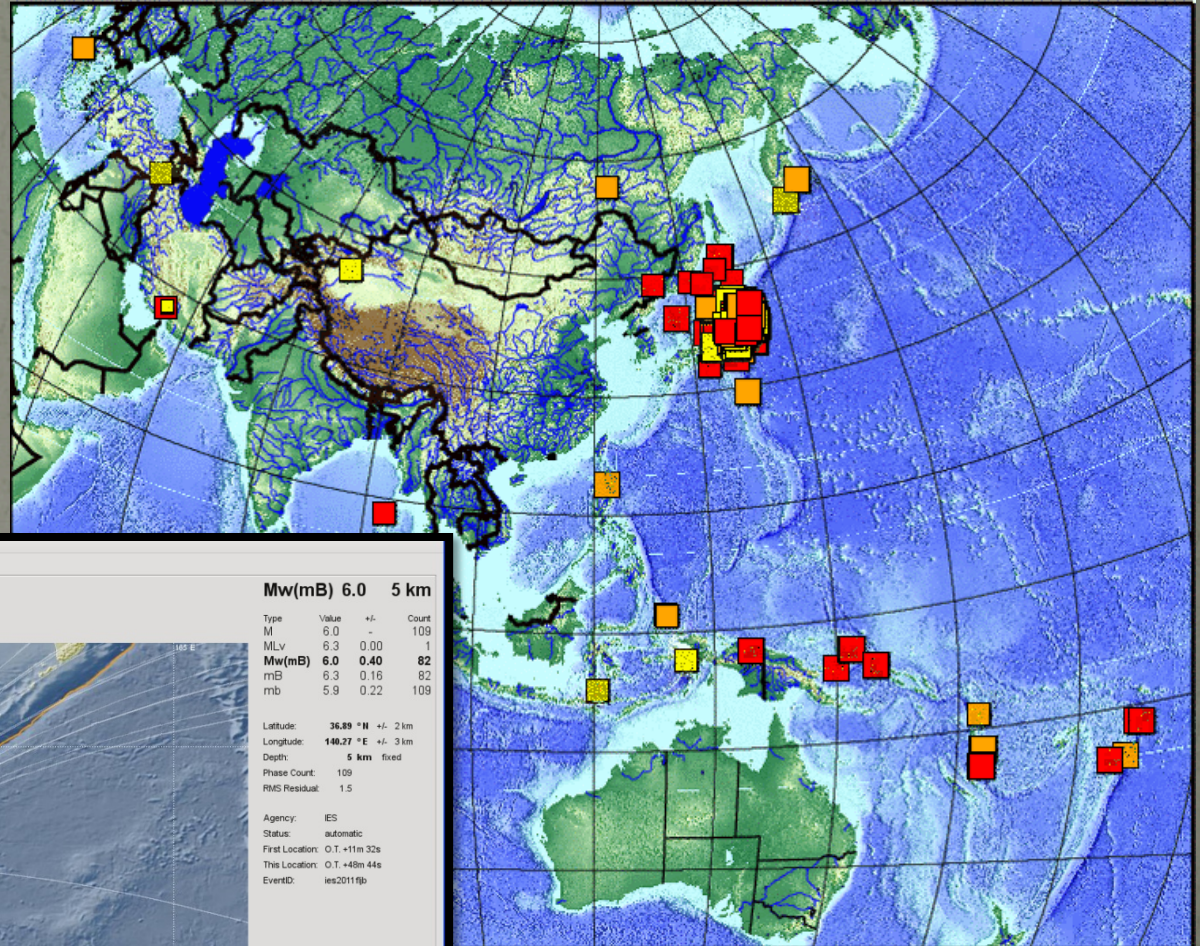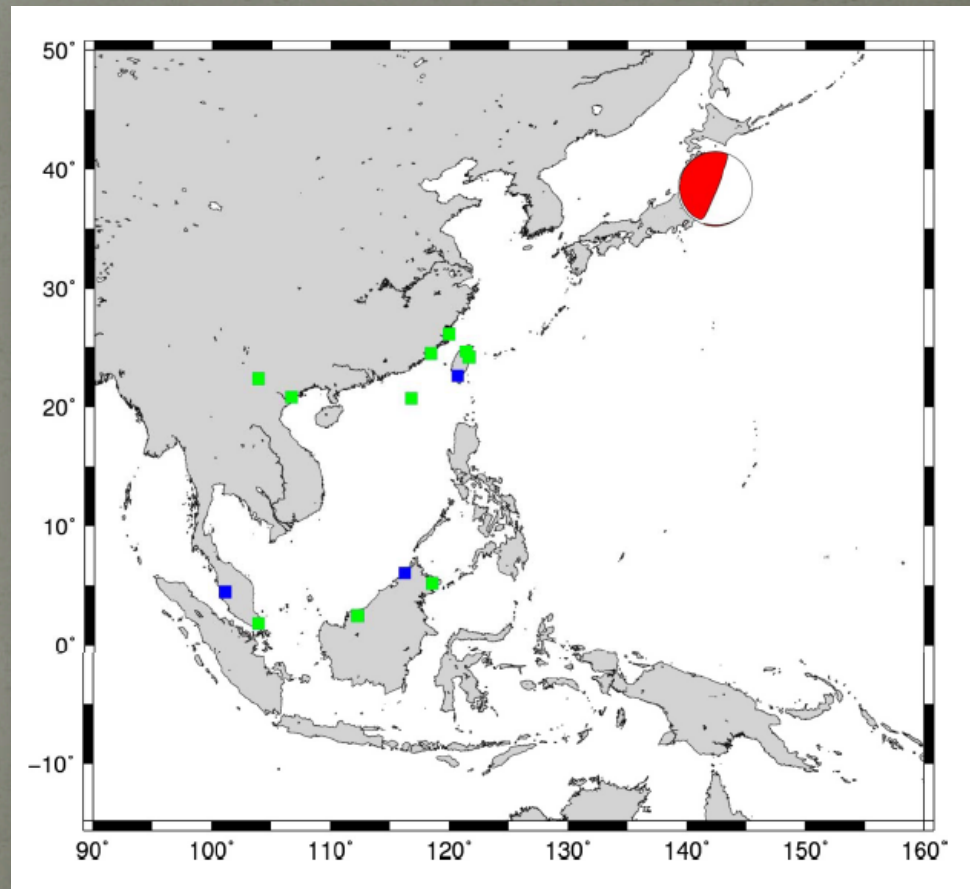
Regional W-Phase Source Inversion


20110311
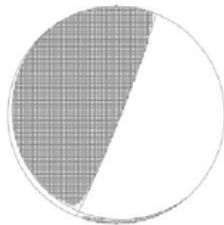
W-phase
Mw=9.08
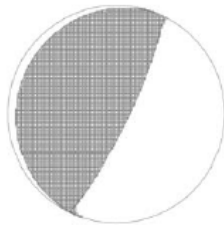
GCMT
Mw=9.12

Geophysical Instrumentation

- Short-period seismic network (CWB)
- Strong-motion seismic network (CWB,IES)
- Broadband seismic network (CWB,IES)
- GPS network (CWB,IES,CGS,MOI,…)
- Borehole strainmeter (IES,CGS)
- Creep meter (IES)
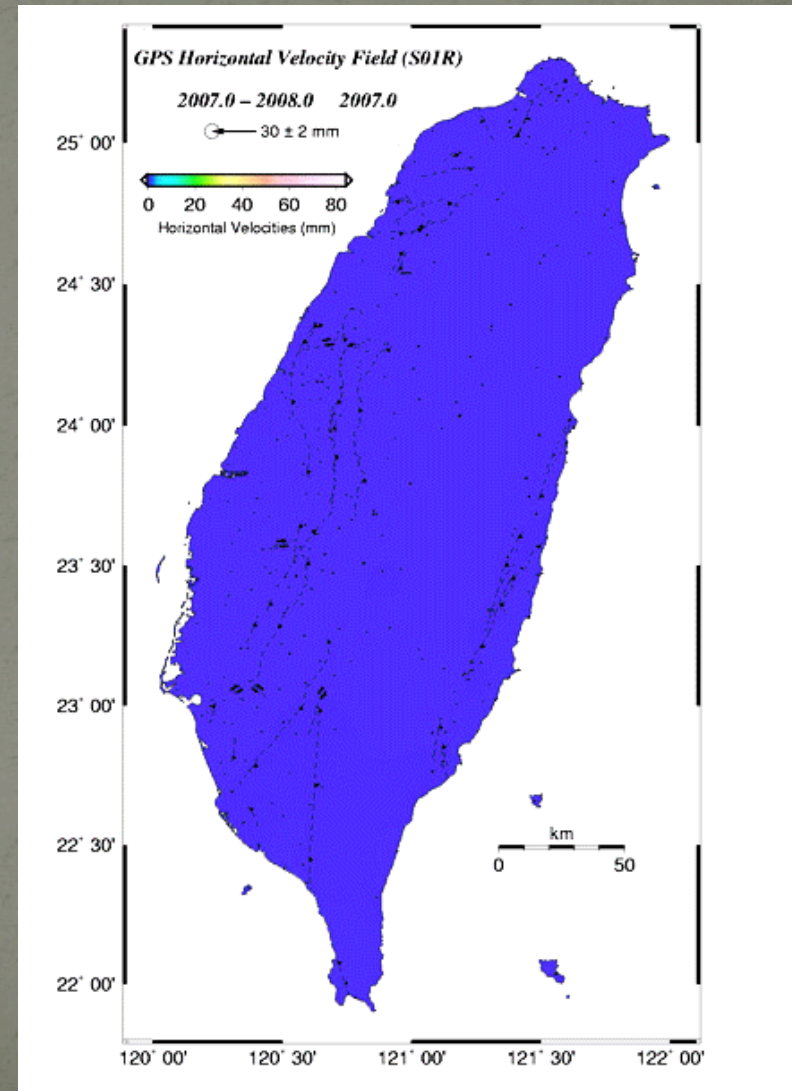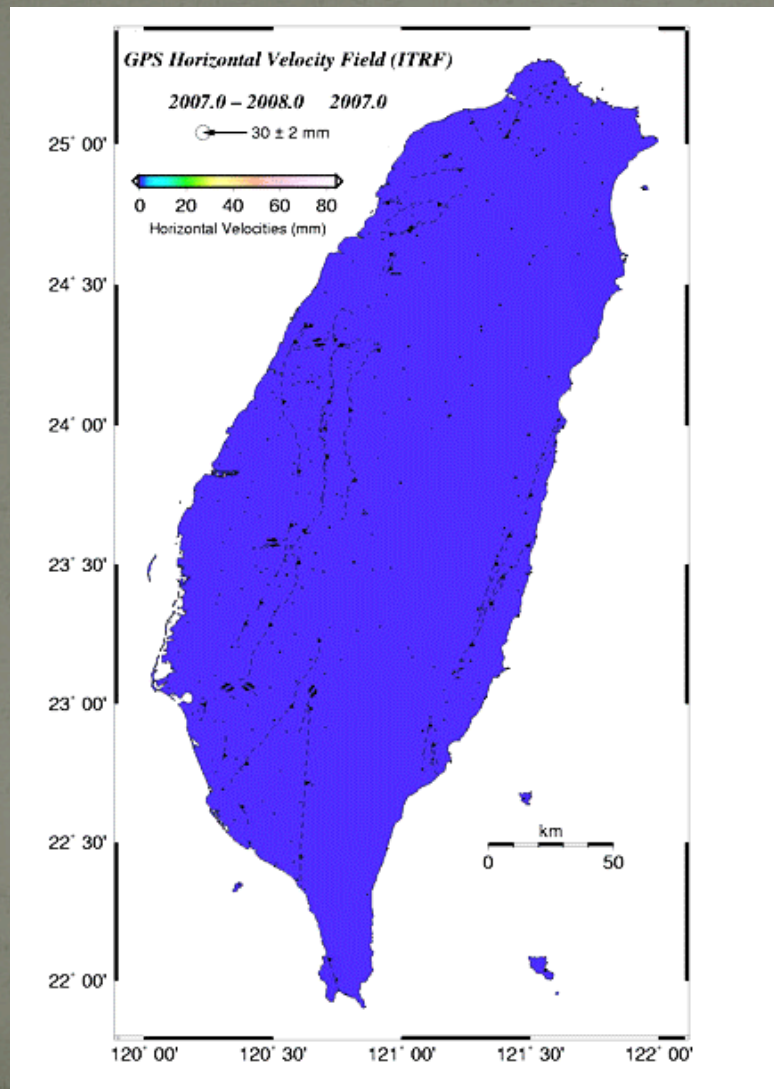- Water level
- Geomagnetic monitoring system
- Gravimeter

Continuous GPS Station Network
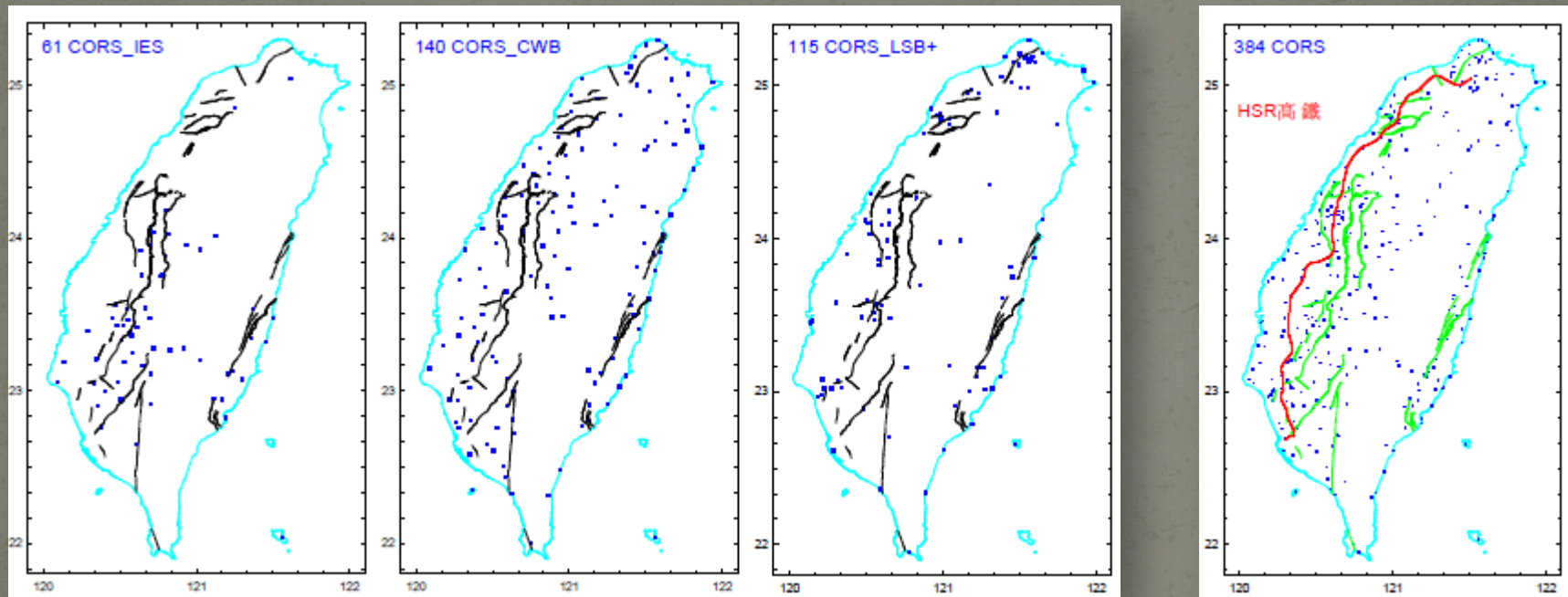
Campaign model GPS stations
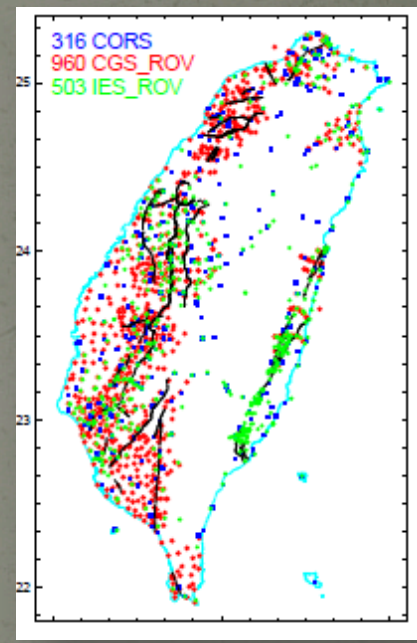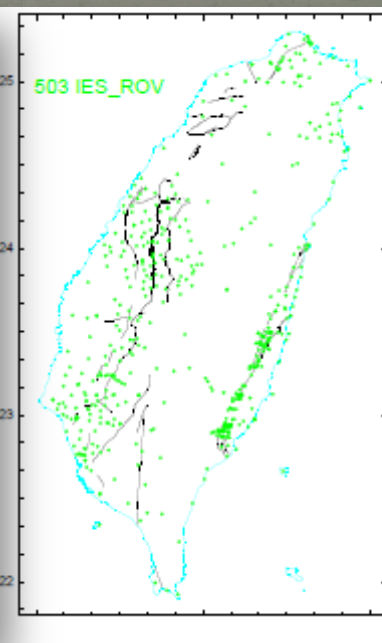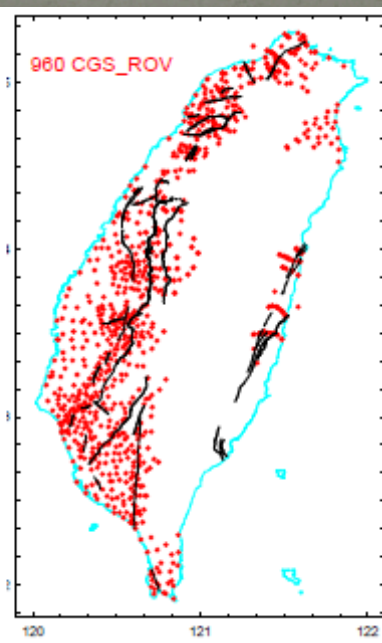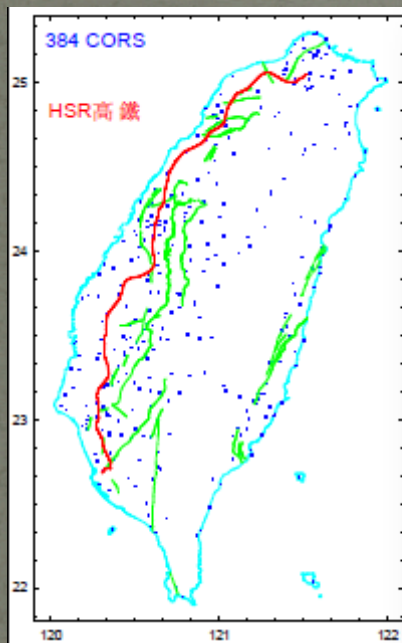
Horizontal Displacement wrt ITRF and S01R

Taiwan Earthquake Research Data Center (TEC
DC)

http://tecdc.earth.sinica.edu.tw

Thank you!