The CWB Downhole Seismic Array and Its Application for Earthquake Observation in Taiwan

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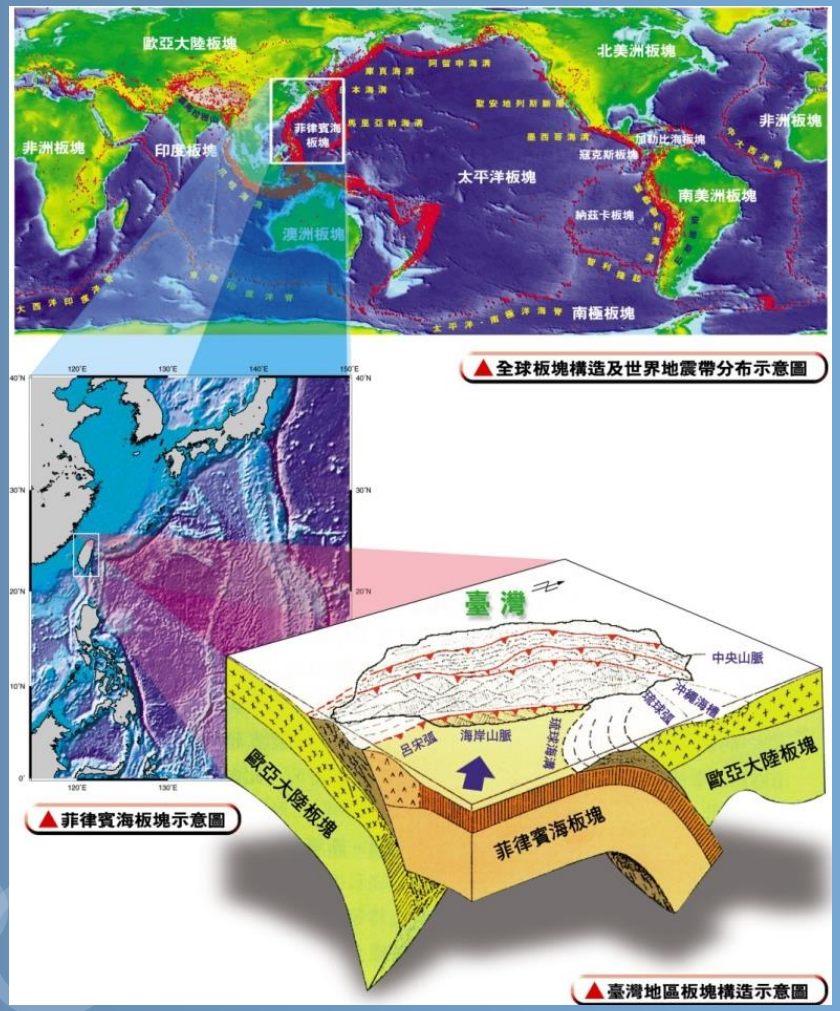
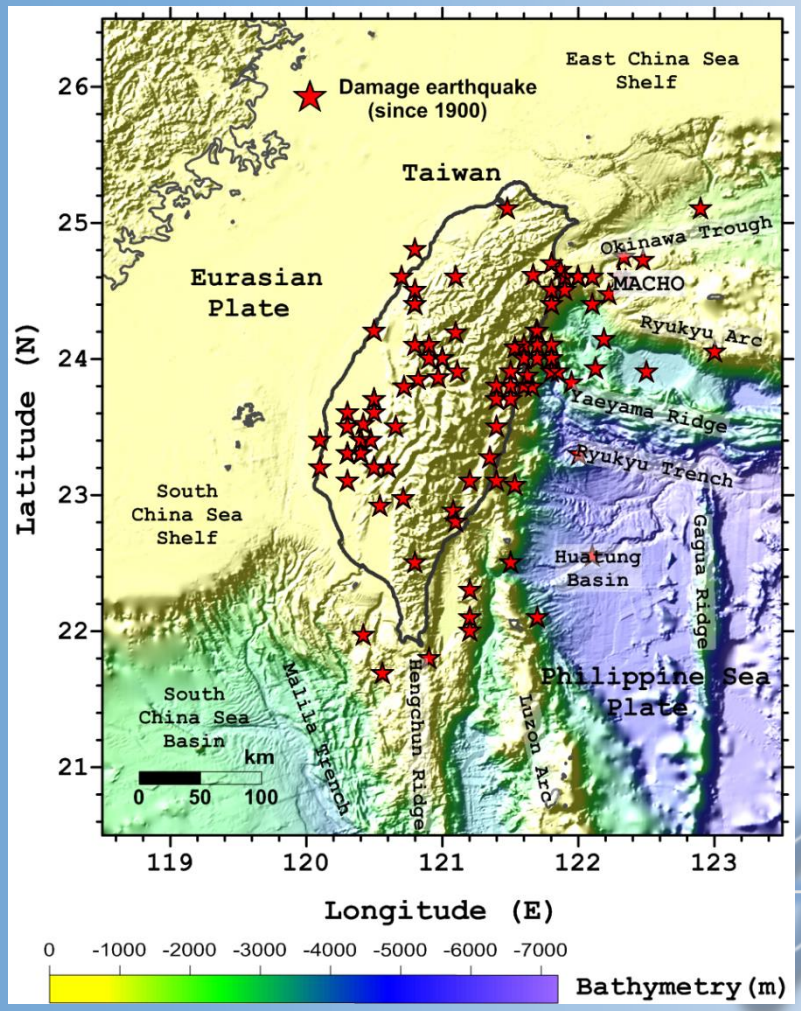
Outline

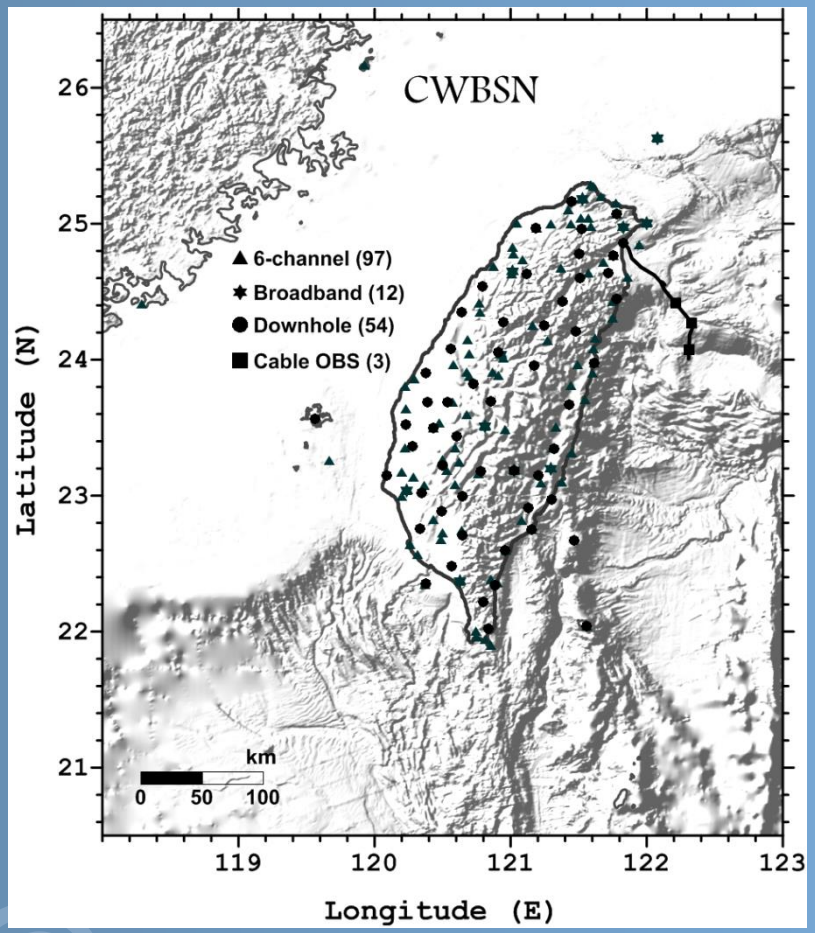
- Introduction
- CWB Downhole Seismic Array
- Applied for Earthquake Observation
- Other Seismic Related Studies
- Discussion and Summary

Seismic Island - Taiwan





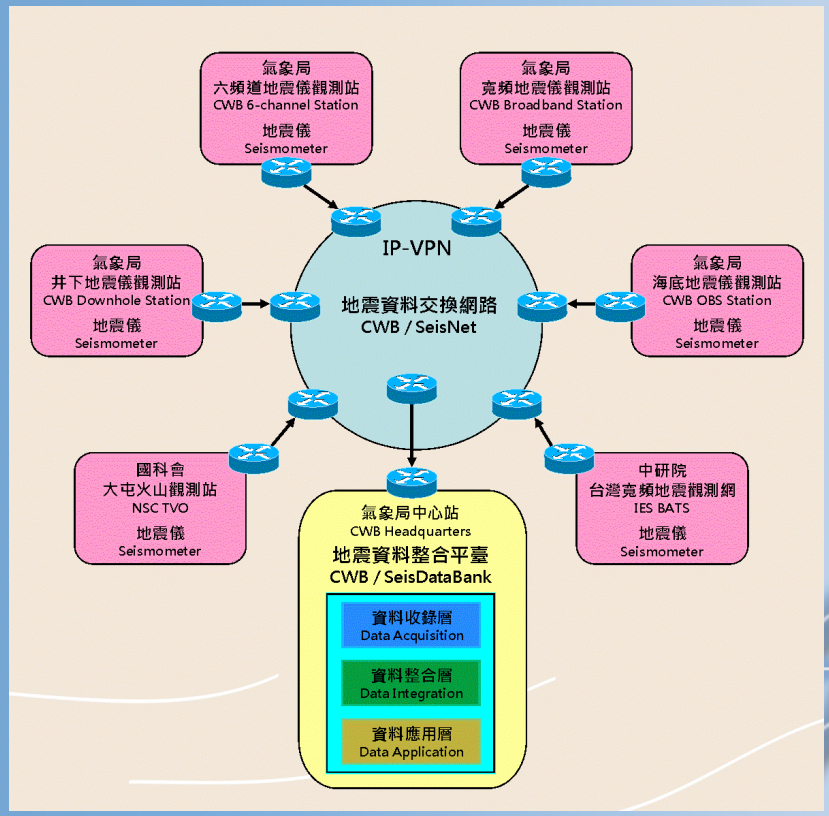
CWBSN Framework



~ 150 stations

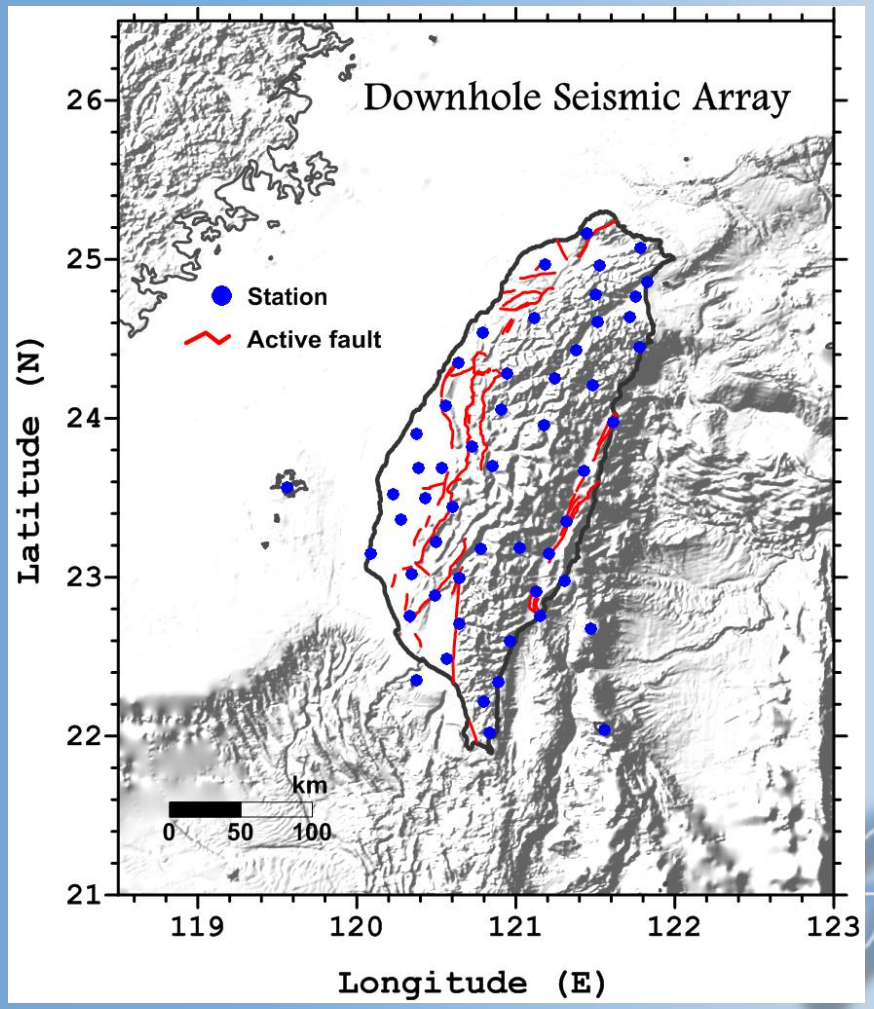
Four type station arrays:

- 6-channel station array
- Broadband station array
- Downhole station array
- OBS station array



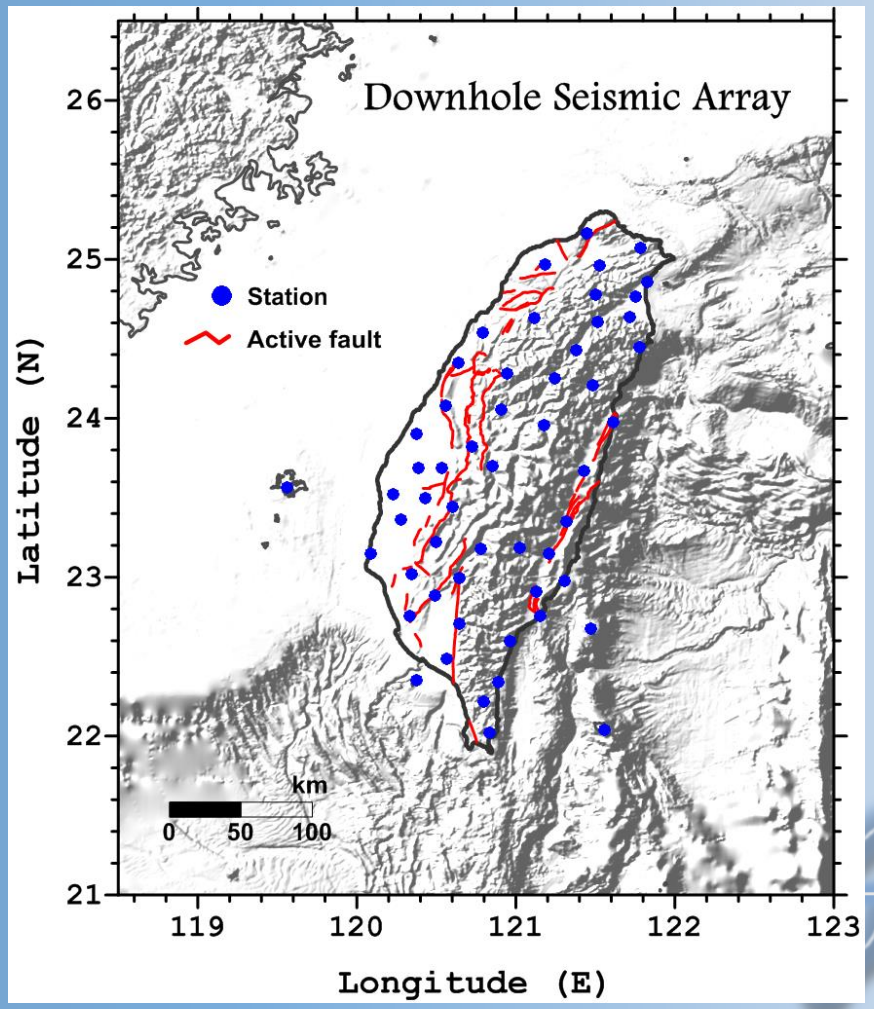
Downhole Seismic Array

- 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 averagely.
- 3 seismometers are installed in a station, include 1 borehole broadband sensor, 1 borehole FBA sensor, and 1 surface FBA sensor.
- 54 stations established, and plan to build 70 stations totally for the next few years.

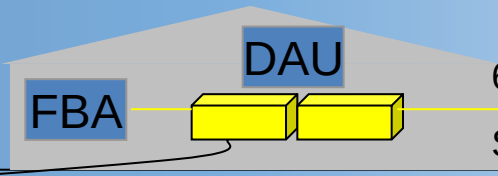


Downhole Seismic Array

- Surface accelerometer –
  - Geotech PA-23、Guralp 5TC
  - 24 bits resolution
  - ± 2g Max. amplitude
  - DC ~ 50 Hz
- Downhole accelerometer –
  - Geotech PA-23B、Guralp 5TB
  - 24 bits resolution
  - ± 2g Max. amplitude
  - DC ~ 50 Hz
- Downhole broadband –
  - Geotech KS-2000、Guralp 3TB
  - 24 bits resolution
  - 120 sec ~ 50 Hz



Downhole Station Configuration



SMART-24R

PA-23

diameter 5 inch

300m

PA-23B

KS-2000B

FBA

BB

18m

grouting

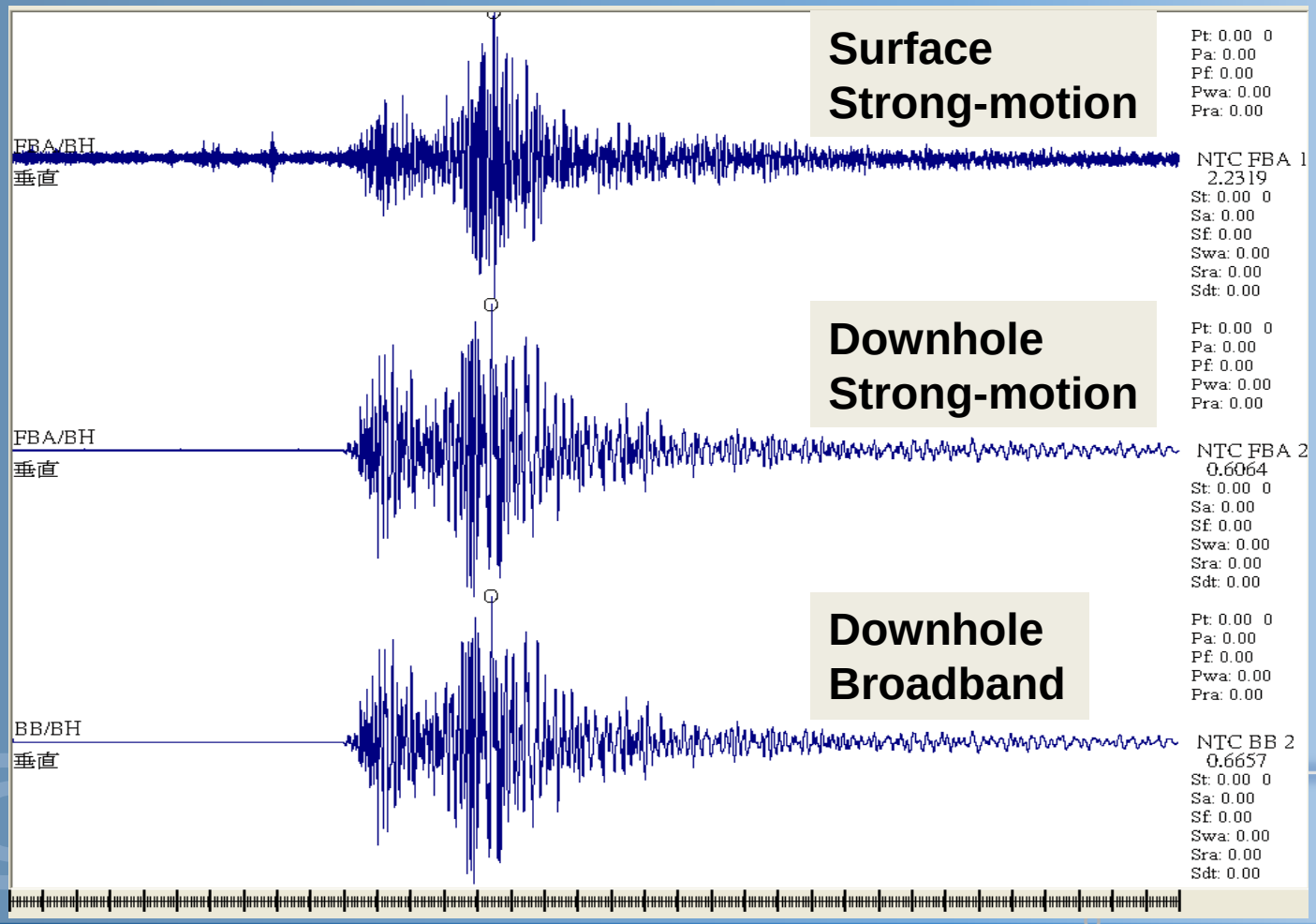
Specification

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

Improvement for Event Recording

2010/3/4 8:18:52 M_L 6.4

Toucheng station



2.23 gal

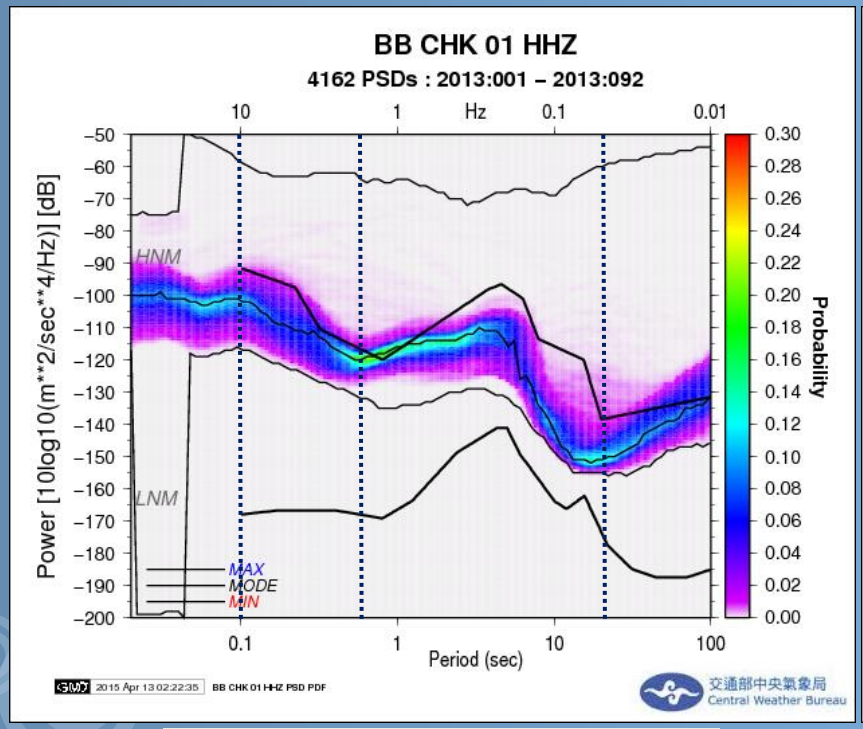
0.61 gal

0.67 gal

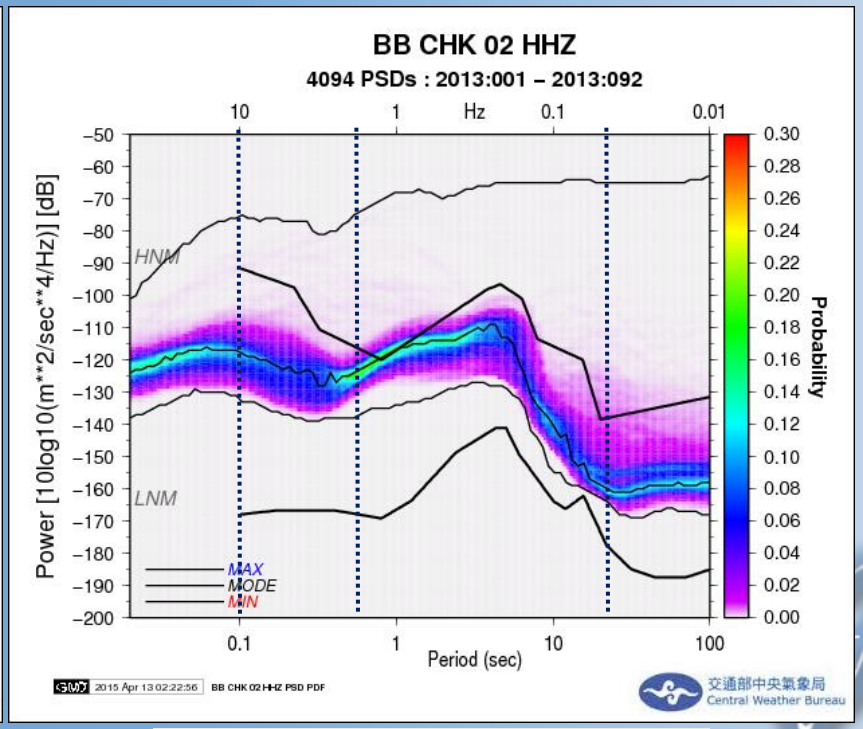
Ambient Noise Level Reduction

- Power Spectral Density (PSD) function for downhole and surface BB sensor:
  - 0.02~0.1 sec (culture noise) : 20 dB down
  - 0.1~0.7 sec (local earthquake) : 10 dB down
  - 0.7~20.0 sec (regional earthquake) : not obviously
  - 20.0~100.0 sec (tele-seismic) : 20 dB down

Chenggong station

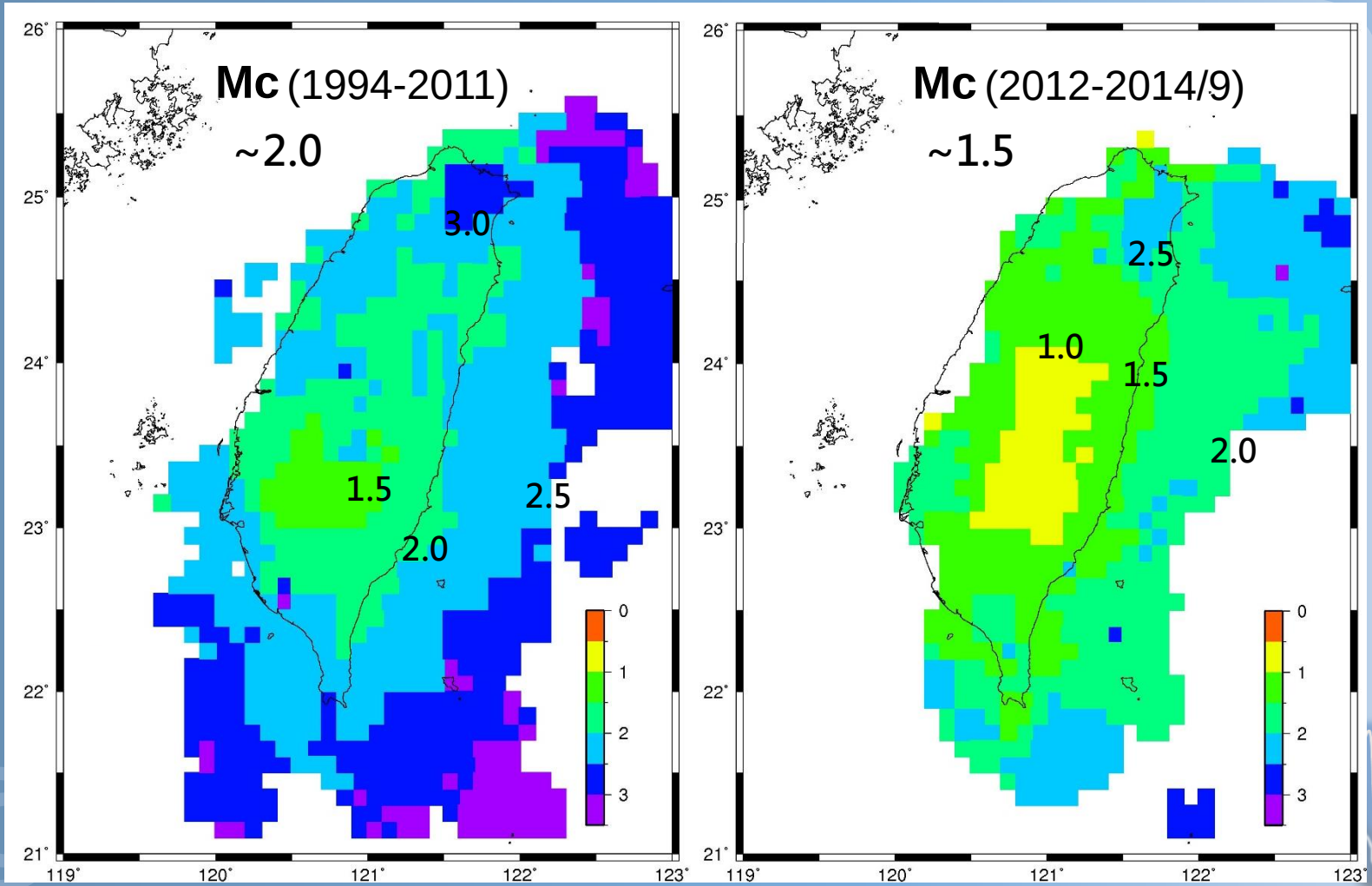


Surface Broadband



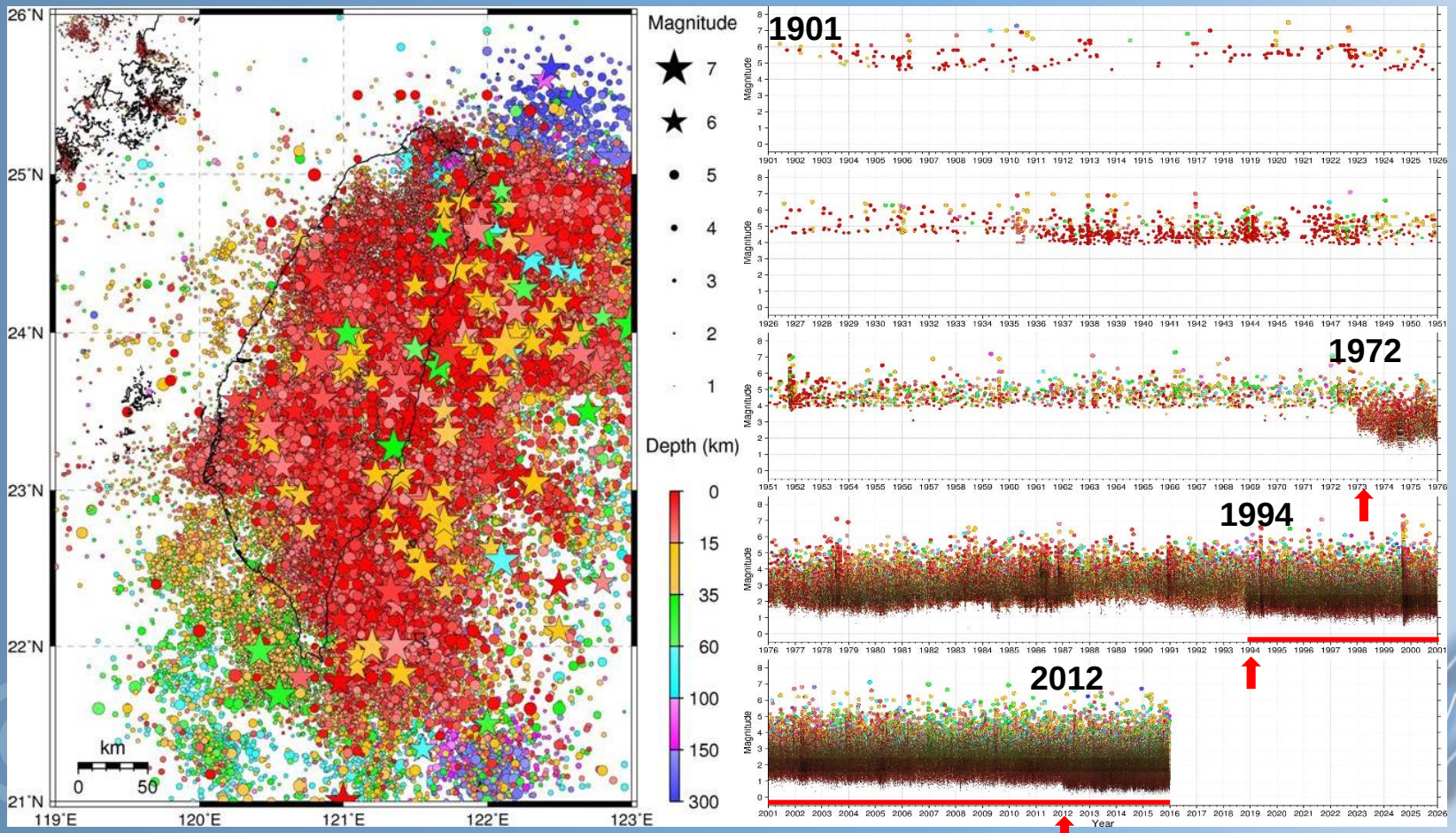
Downhole Broadband

Magnitude of Completeness of CWBSN



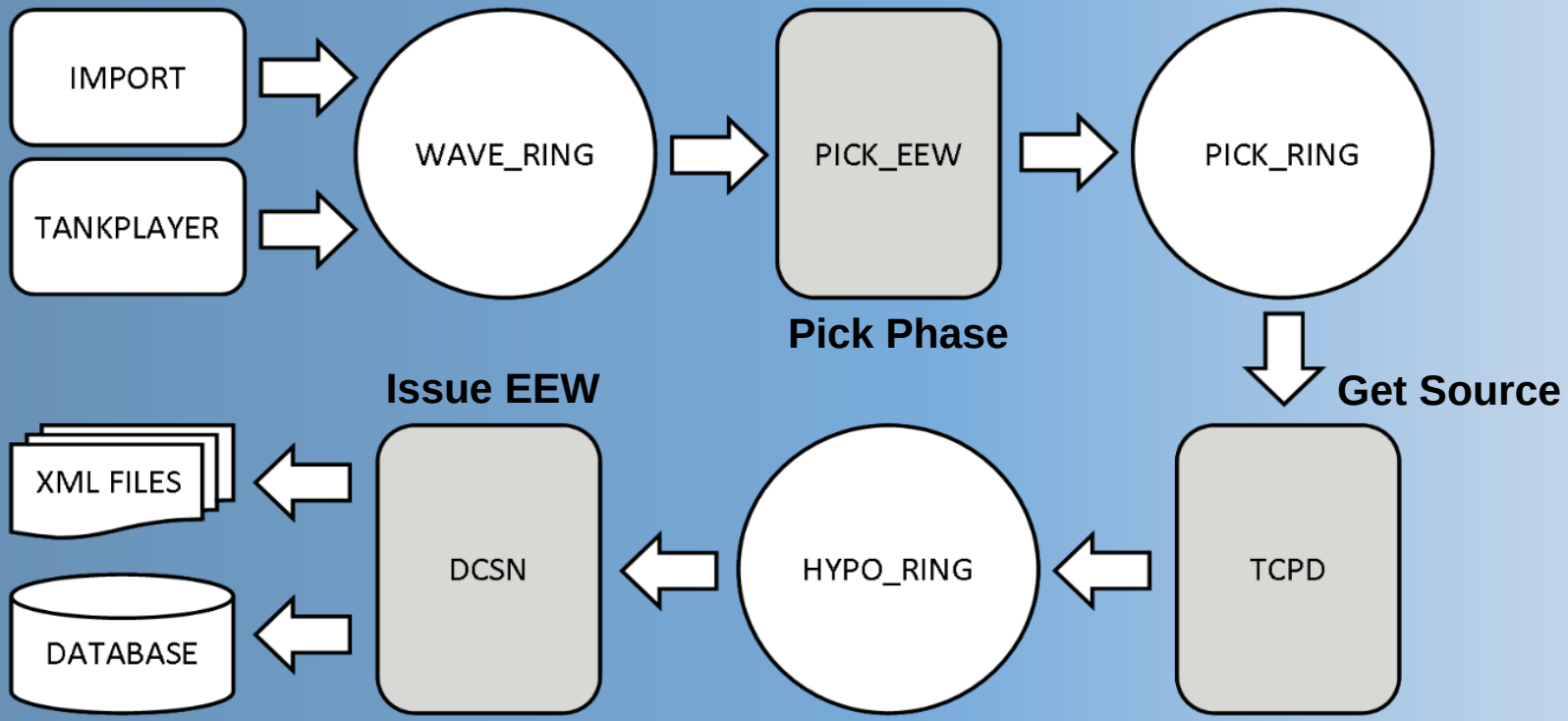
Progress for Seismicity Observation

1901~2015 654,775 events totally
1901~1972 ~45 events/year **1973~1993 ~4,500 events/year**
1994~2011 ~20,000 events/year **2012~ ~40,000 events/year**



EEW Procedure

- Using STA/LTA algorithm
- Determine P arrival, Pd, Pv, Pa



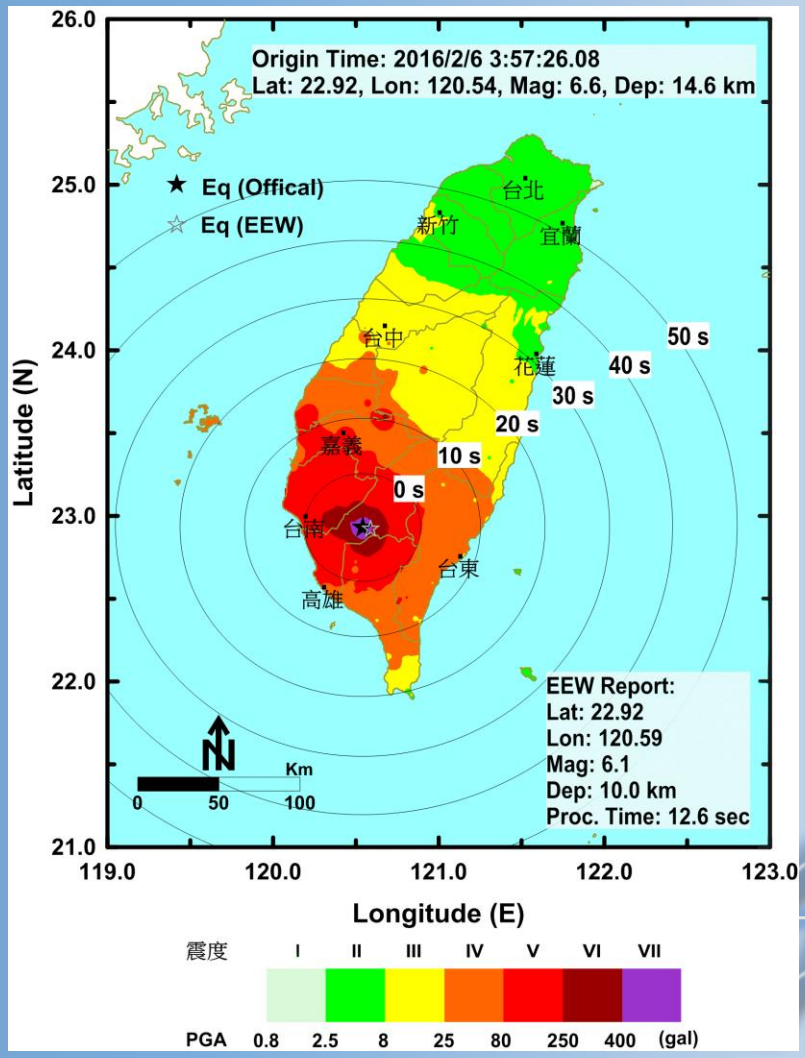
- M > 4.5 issue report
- Take the 3rd report
- $\Delta M > 0.5$ or $\Delta r > 20$ km update report

- Threshold: 6 stations
- Epicenter: Geiger's method
- Depth: grid search
- Magnitude:

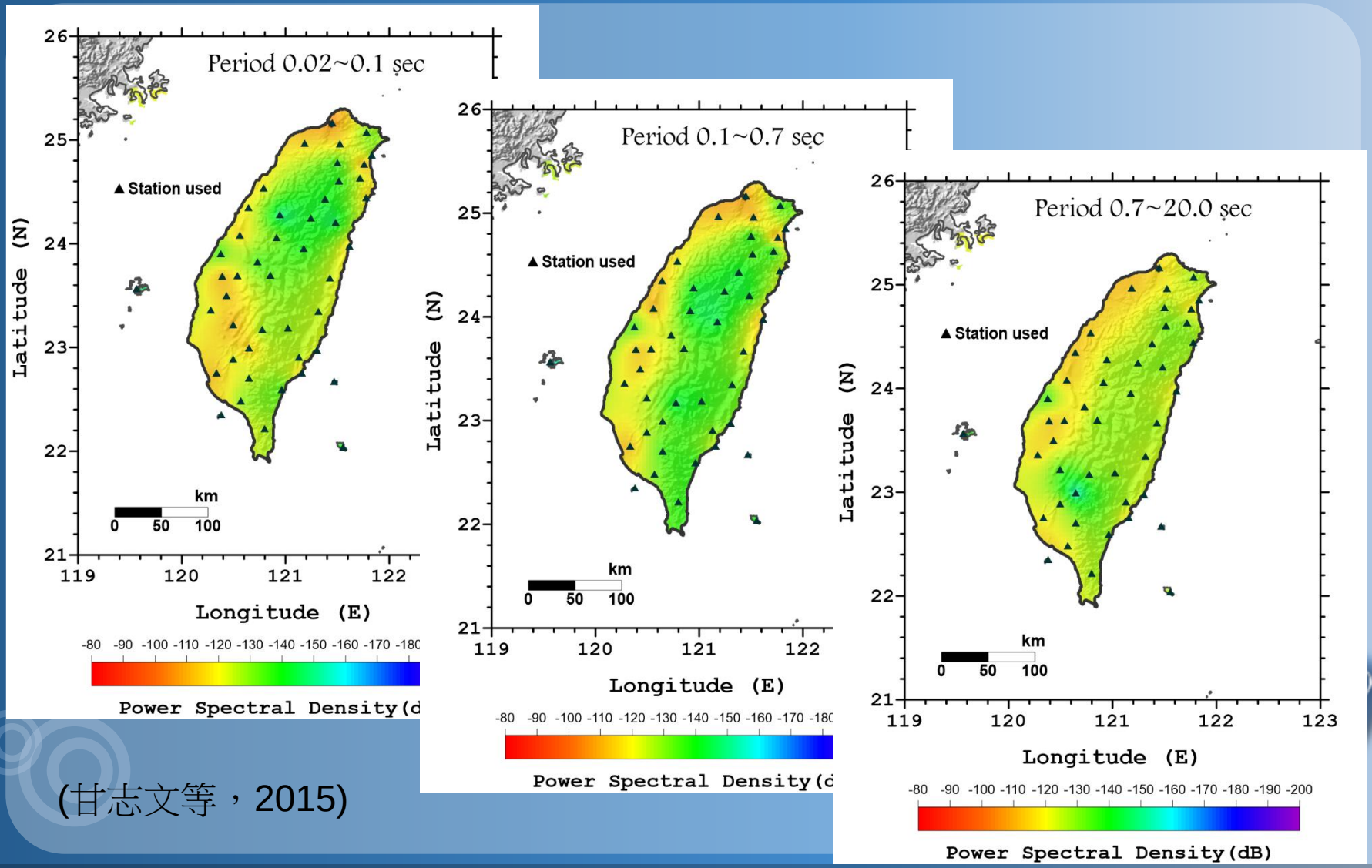
$$M_{P_d} = 5.000 + 1.102 \times \log_{10}(P_d) + 1.737 \times \log_{10}(r)$$

EEW for 2016 M6.6 Meinong Earthquake

Processing time：12.6 sec



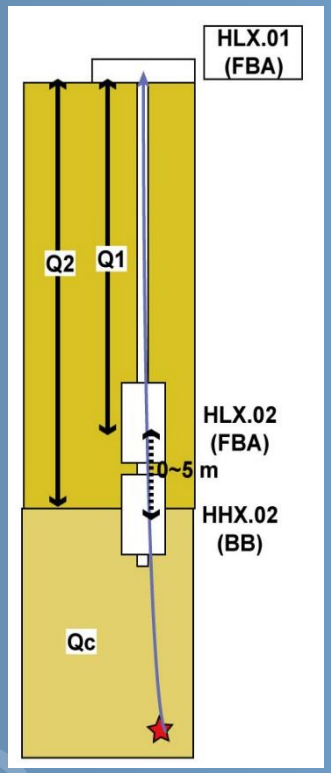
Seismic Ambient Noise Study



(甘志文等，2015)

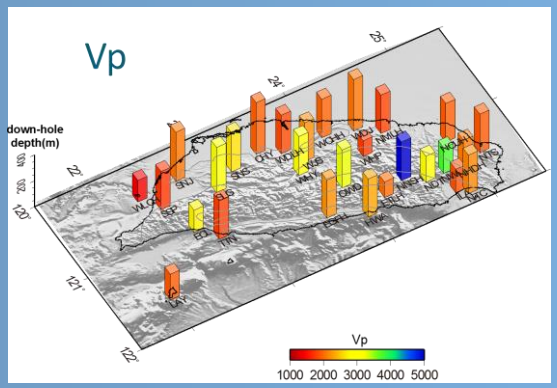
Near-Surface Sediment Study – Case I

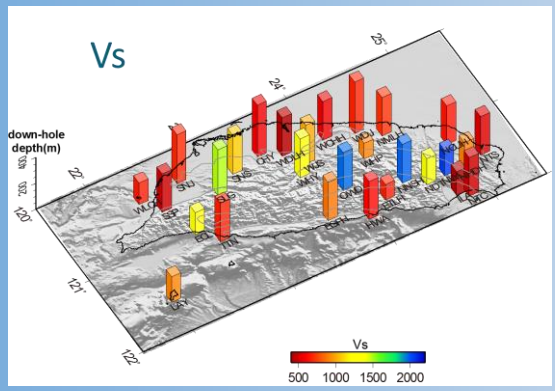
Velocity and Attenuation Model

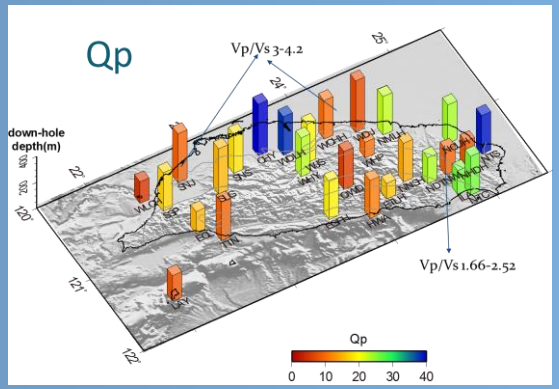


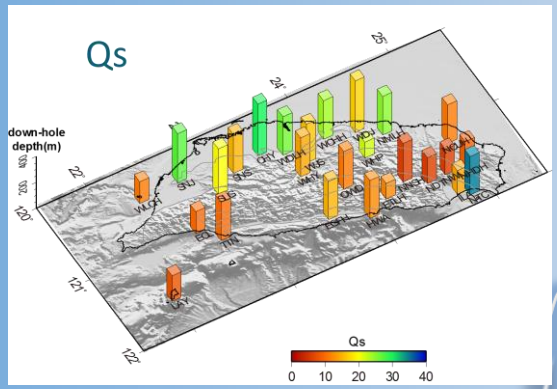
(Q1=~Q2)

Spectral ratio method







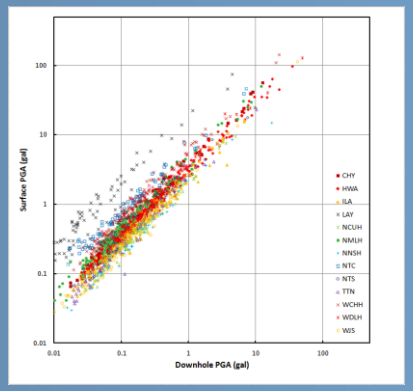


(馬國鳳等，2014)

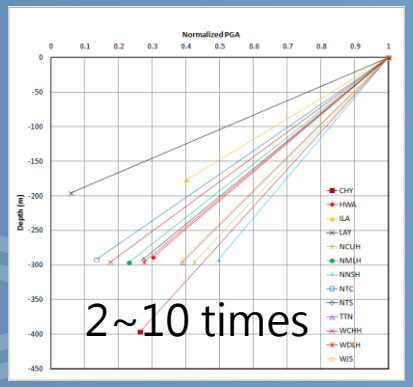
Near-Surface Sediment Study – Case II

Site Effect

Surface PGA vs Downhole PGA

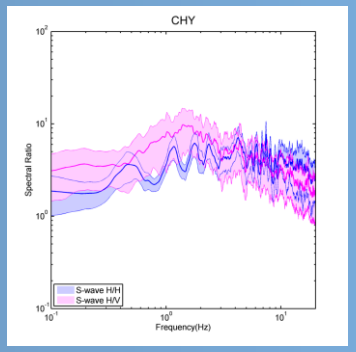


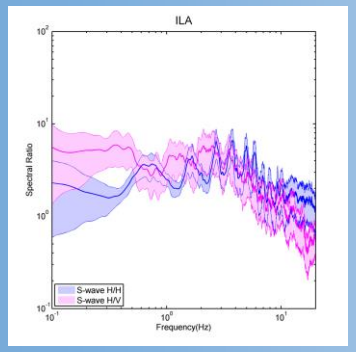
PGA amplification

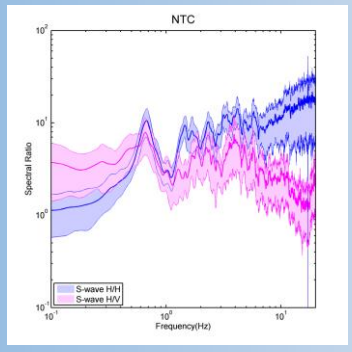


Empirical transfer function

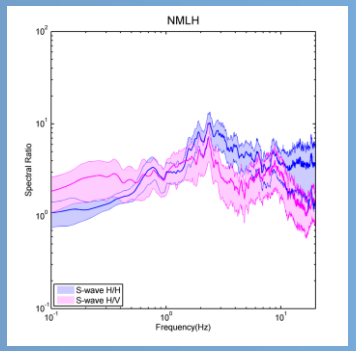
Plain area

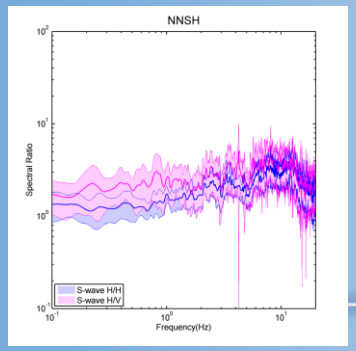


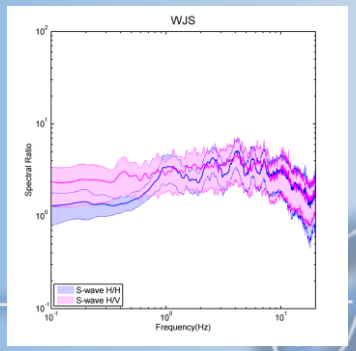




Mountain area



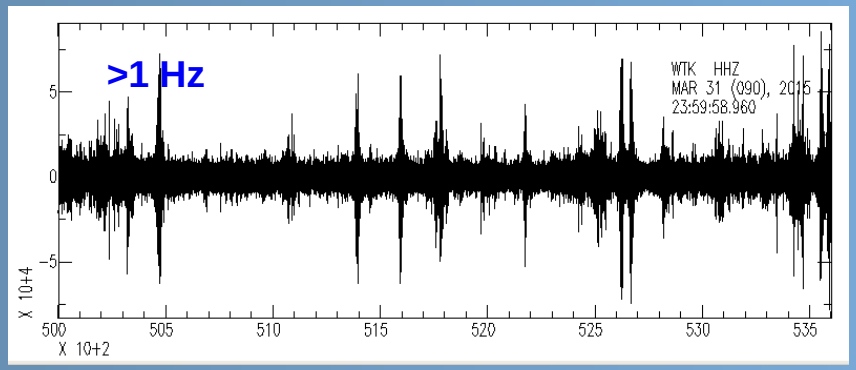


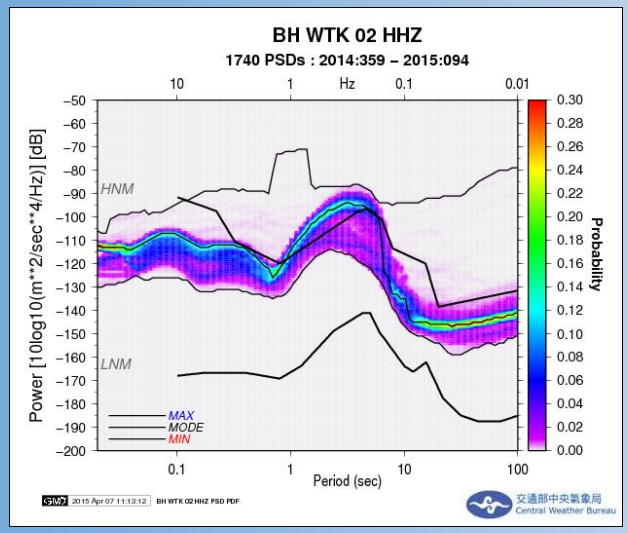


(溫國樑等，2014)

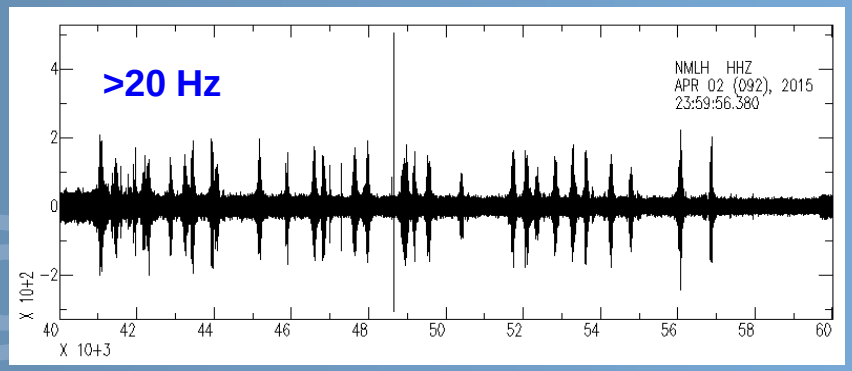
Frequent Noise Interference Problem

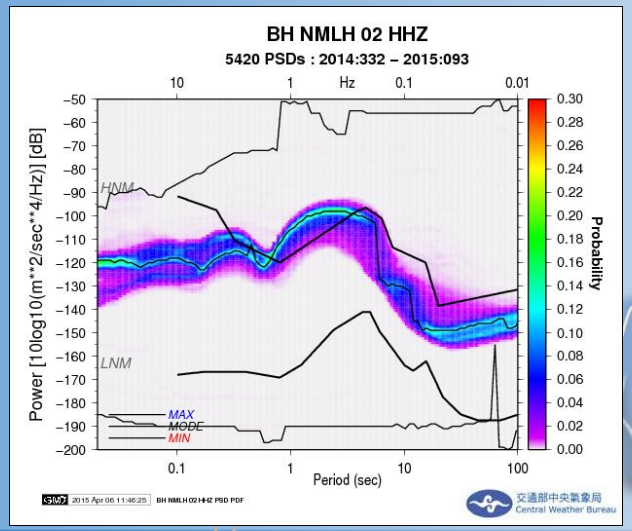
High speed train signal



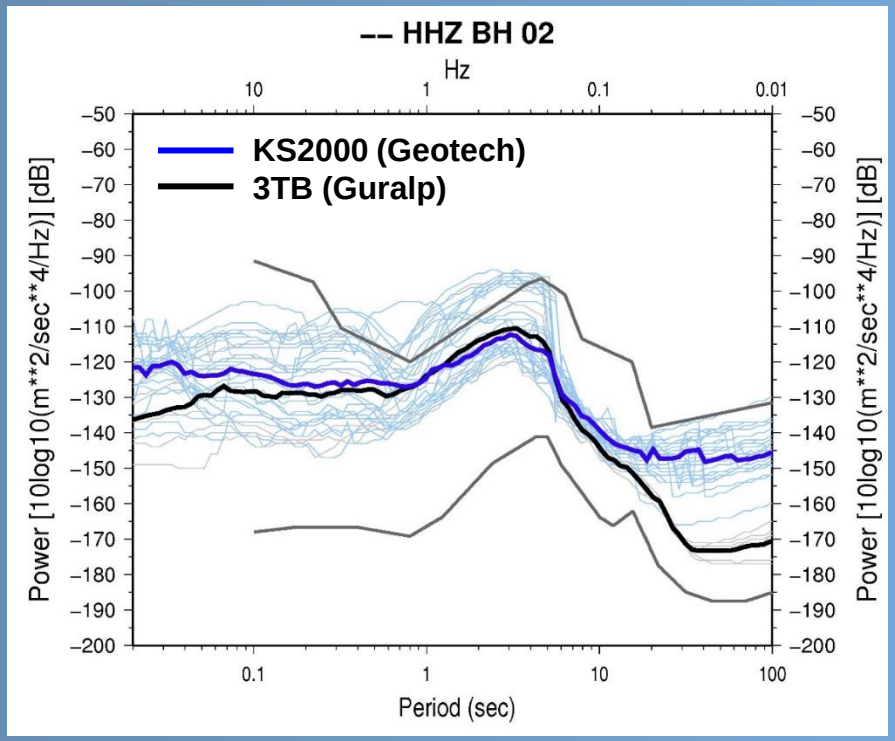


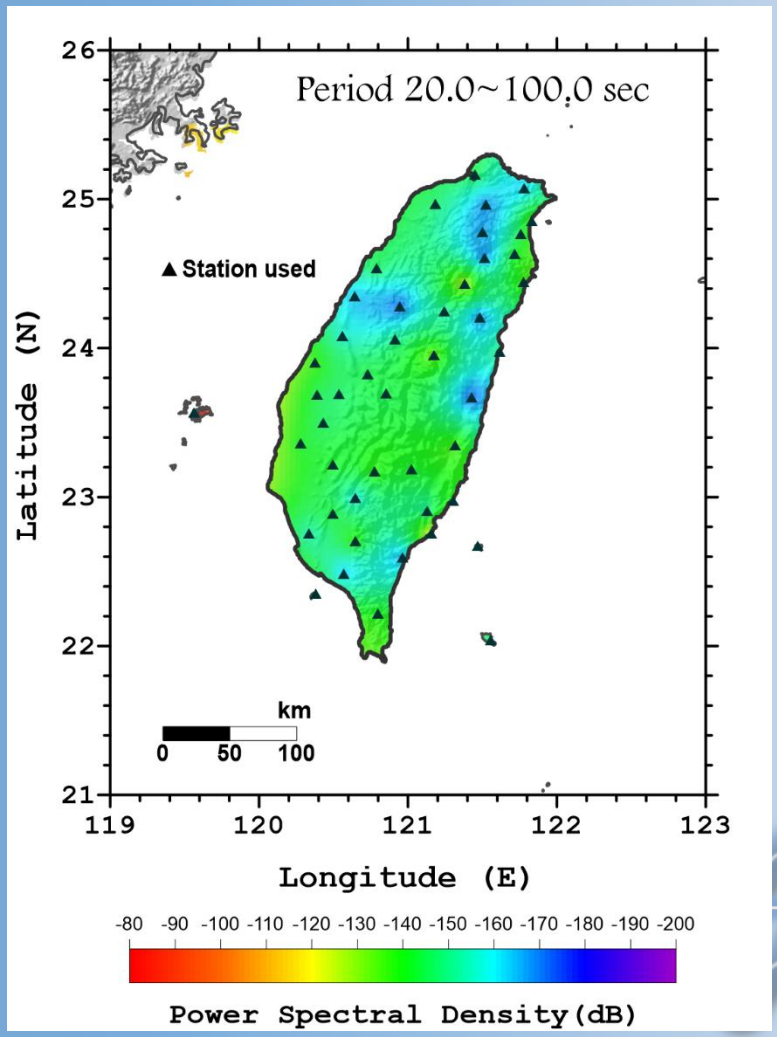
Wastewater treatment signal



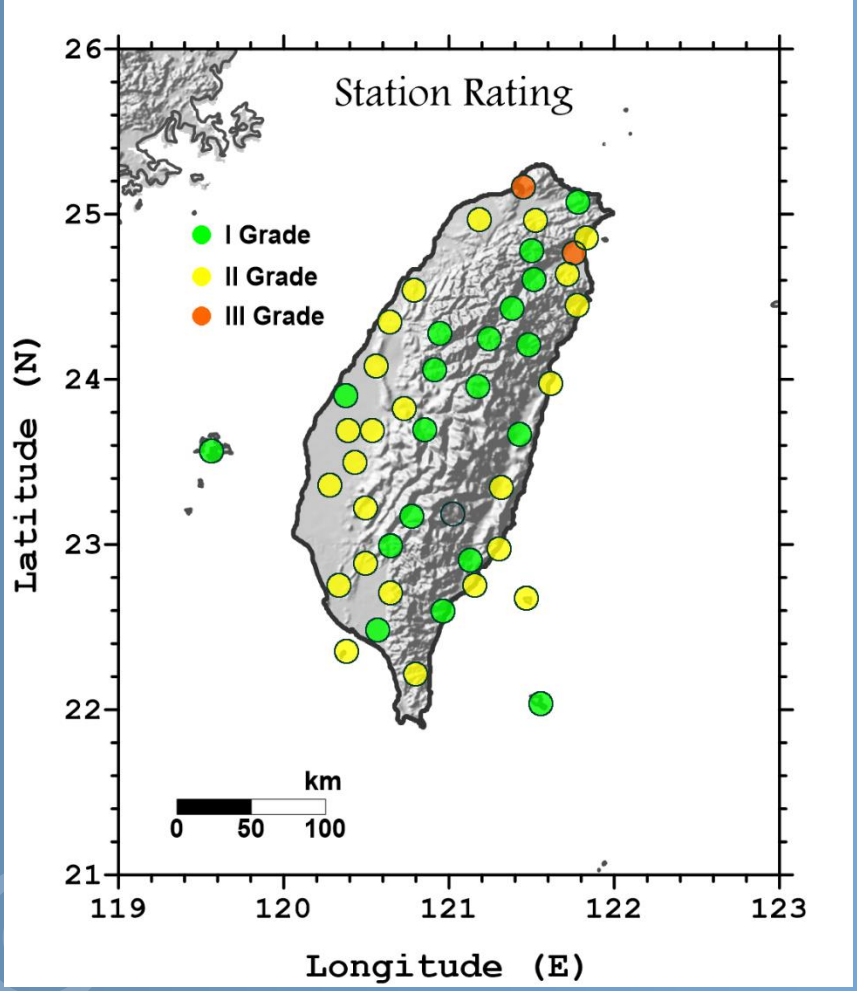


Long Period Resolution Problem





Improvement Plan



Station Classifications:

- I Grade
  - Operation well
  - Routine maintenance
- II Grade
  - Upgrade considered
  - Replace instrument
- III Grade
  - Upgrade required
  - Change site

Summary

- The downhole seismic array has gradually become the prospective backbone network and actually proved to be useful for seismic operations in Taiwan.
- With high quality data being available, kinds of related seismological operations and researches are comprehensively conducted.
- CWB will keep improving the performance of seismic array, such as add more stations and upgrade the resolution of sensors in the future.

The End

Thank you for your attention!