Coseismic Groundwater Level Changes and its Mechanism, Taiwan, 2003~2004

Wen-Chi Lai[1], Tzay-Tzong Tsai[1],
Chjeng-Lun Shieh[1], Naoji Koizumi[2]

1.Disaster Prevention Research Center,
National Cheng Kung University, Tainan, Taiwan R.O.C

2. Geological Survey of Japan,
Agency of Industrial Science and Technology, Japan

DP RC

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- Problem Statement
- Goals of Our Work
- Methodology
- Observation
- Result
- Discussion
- Summary

Problem Statement

- The well-aquifer system as a strain meter
- The limitation of the observation

  strain sensitivity?
- The responses to the earthquake faulting

  Type? Time and Spatial Distribution?
- Mechanism of the coseismic groundwater level (GWL) change.
- Application for the precursor research

Goals of Our Work

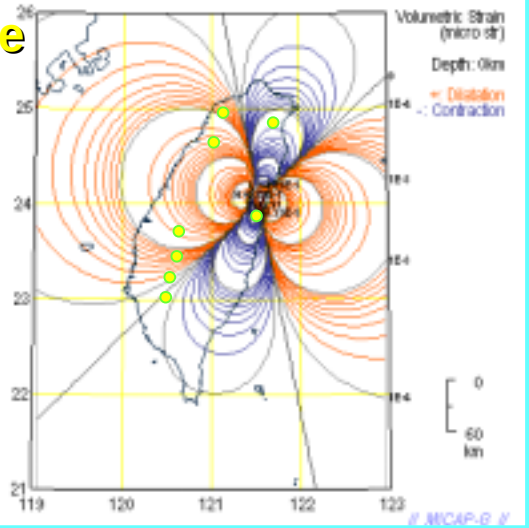
- Estimate the strain sensitivity of observation wells from tidal analysis and coseismic response.
- Check the possible mechanism of observation
- Using the high resolution observation to clarify the mechanism of the coseismic GWL changes in Taiwan

Methodology

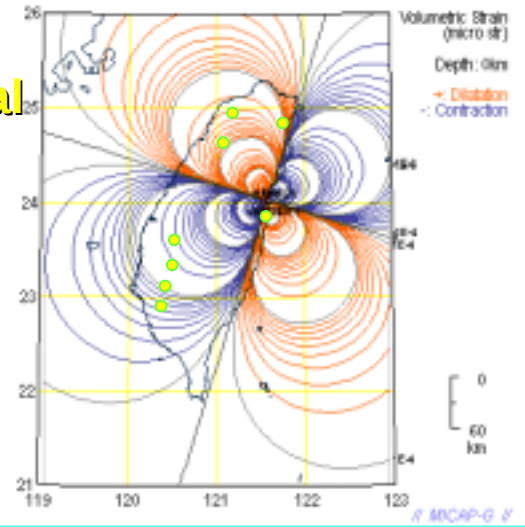
- Using Baytap-G Program to derived the Tidal component of observed groundwater level
- Derived the tidal potential from ETERNA Program
- Determined the static strain sensitivity by cross spectrum and tidal analysis method
- Derived the coseismic static volumetric strain using Okada(1992) dislocation program code

Using the Dislocation Model to Determinate the Static Volumetric Strain

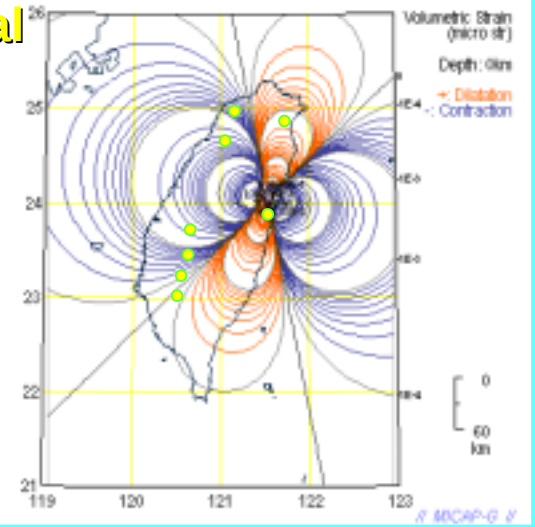
Reverse Fault



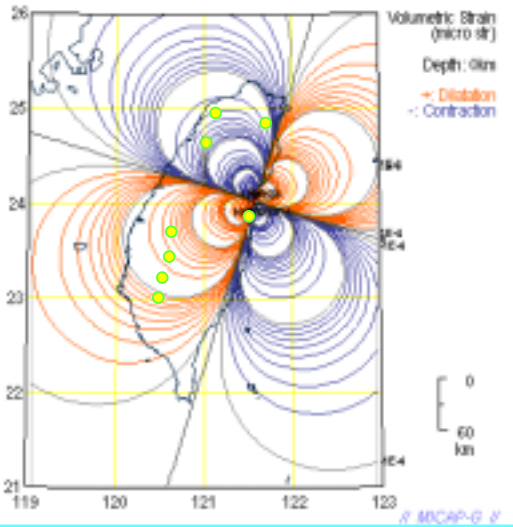
Left Lateral



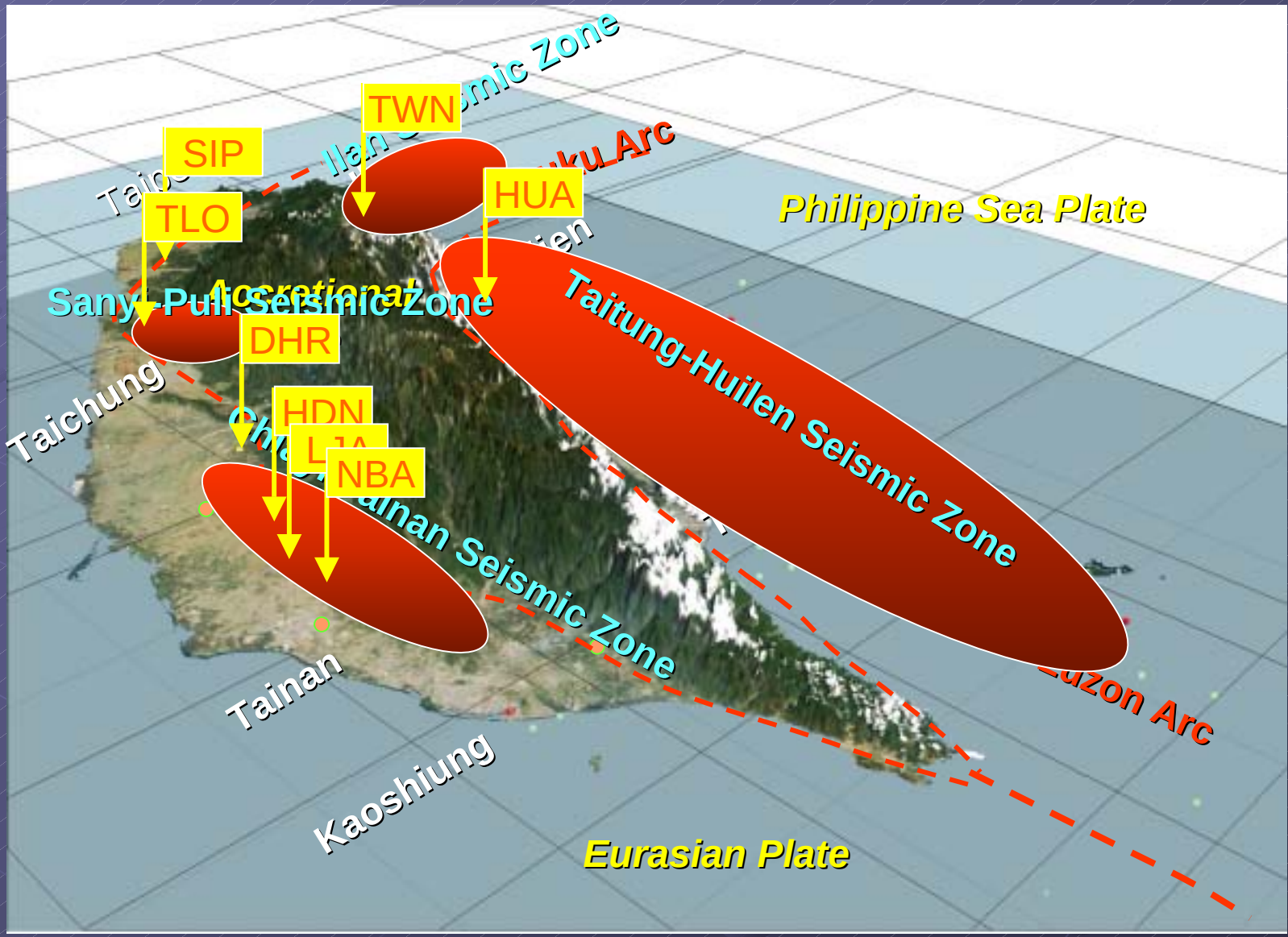
Normal Fault



Right Lateral

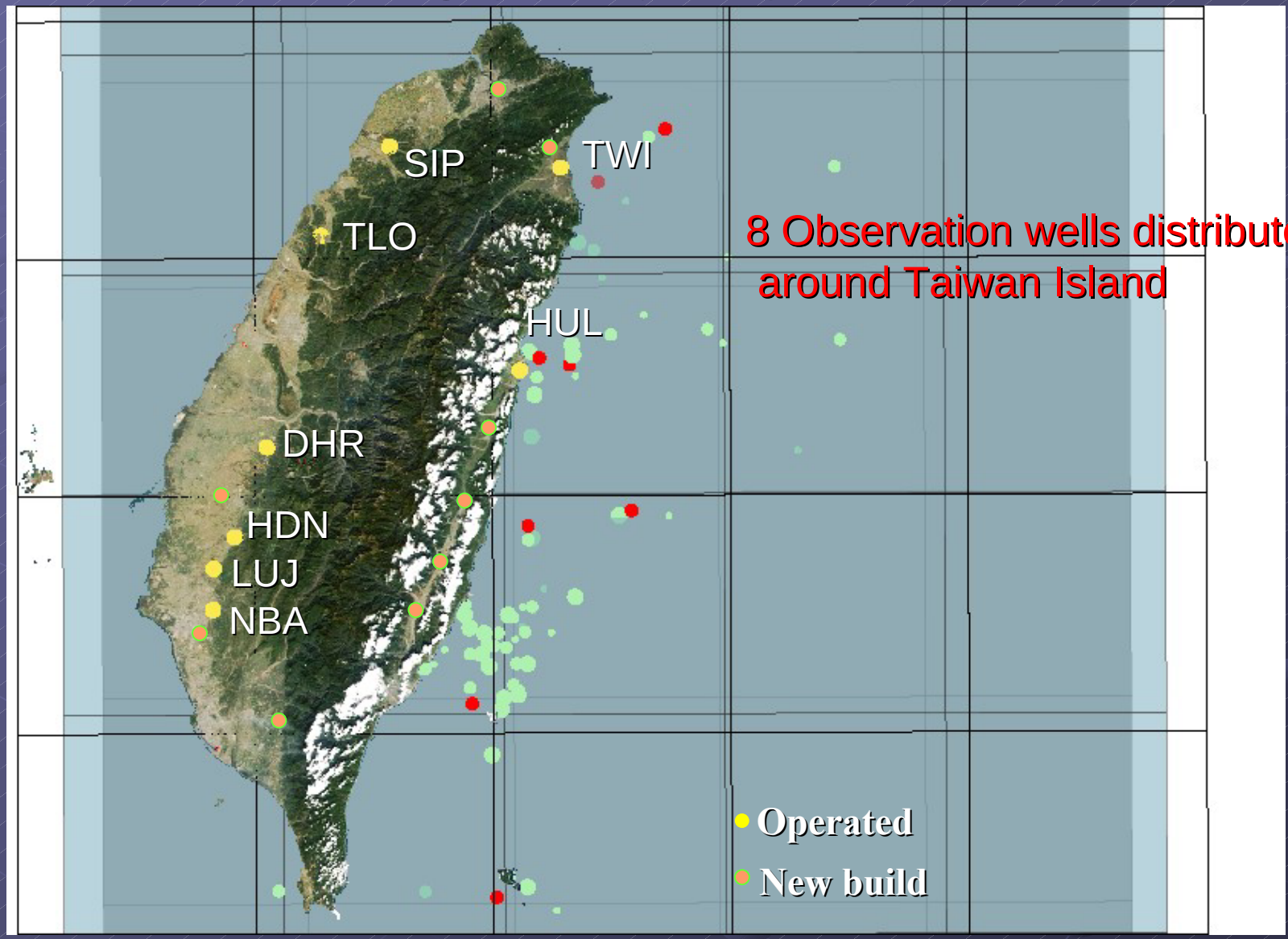


Observation



till 2003/12

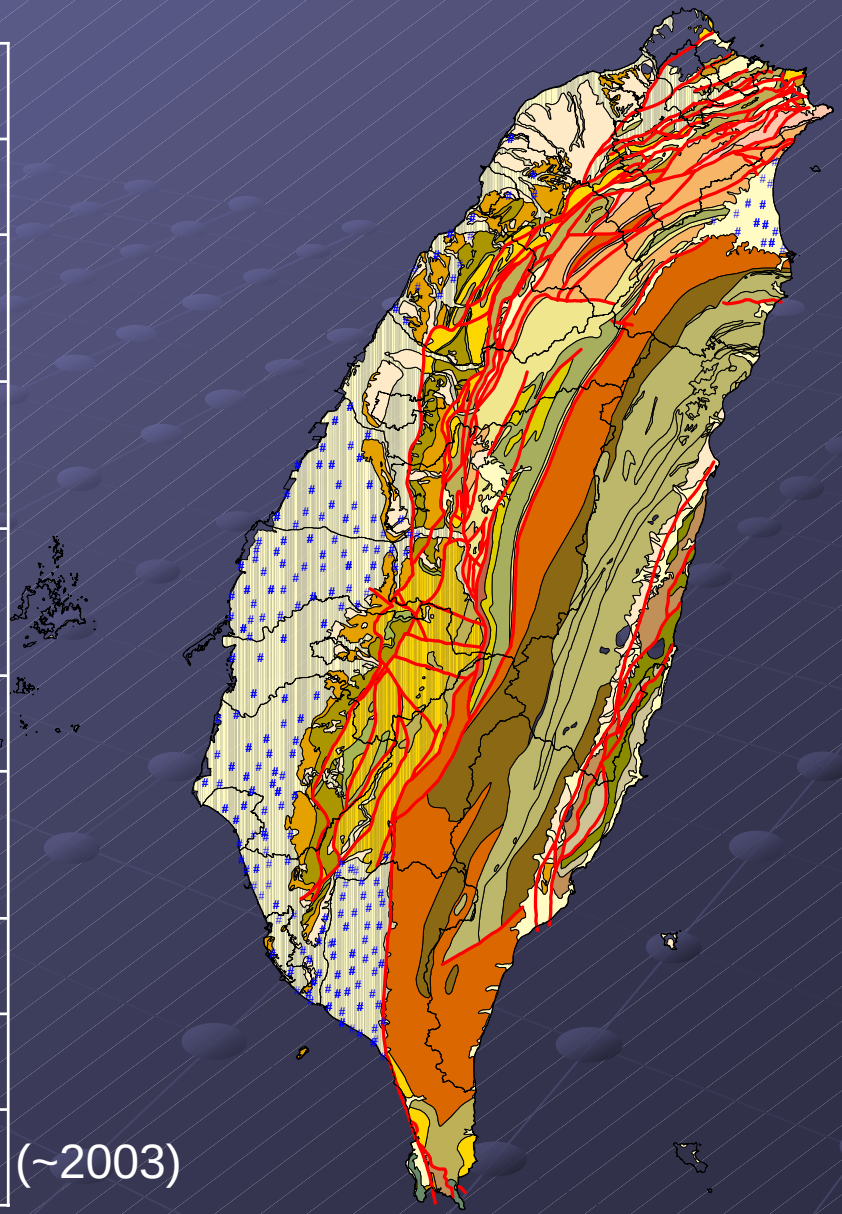
Observation



2003/12~2004/5 Total 36 Events M>5

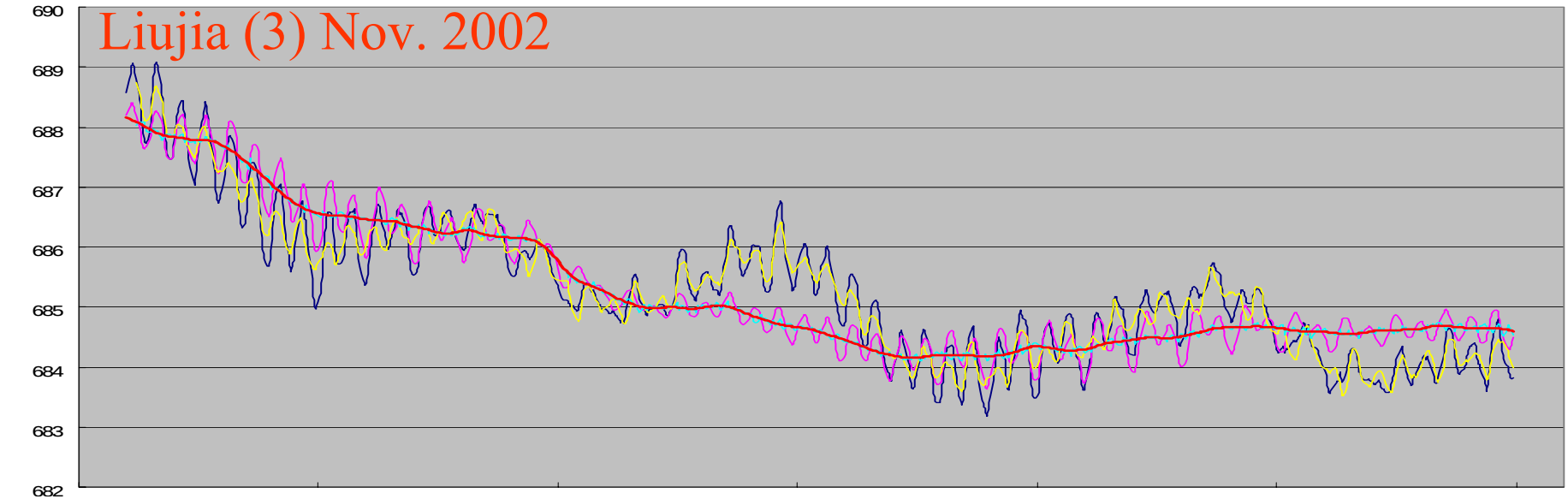
Groundwater Monitor Network of Taiwan

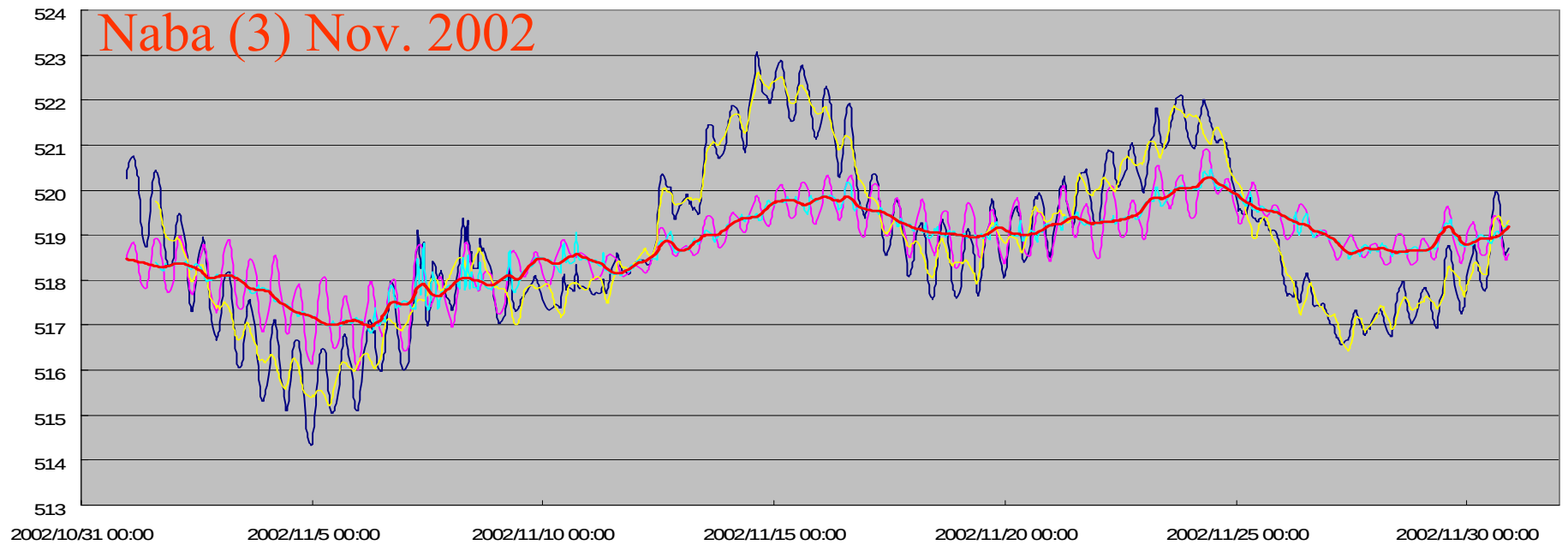
Sub-Province	Site	Well
Taipei Basin	2	4
Taoyuan Tableland	1	2
Hsinchu-Miaoli Area	16	35
Choshui River Alluvial Fan	70	193
Penhu Island	16	35
Chiayi-Tainan Area	45	114
Pingtung Plain	55	132
Ilan Plain	20	36
Total	239	550



(~2003)

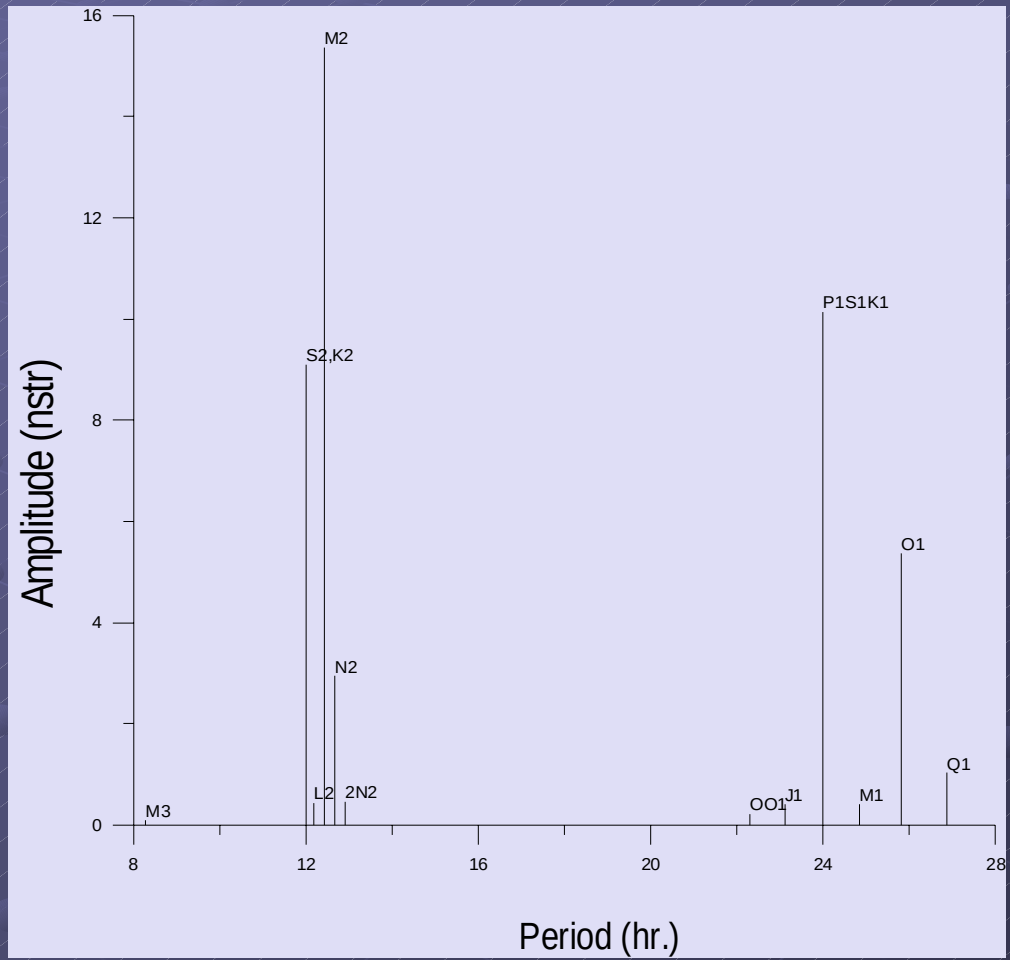
Observation Data





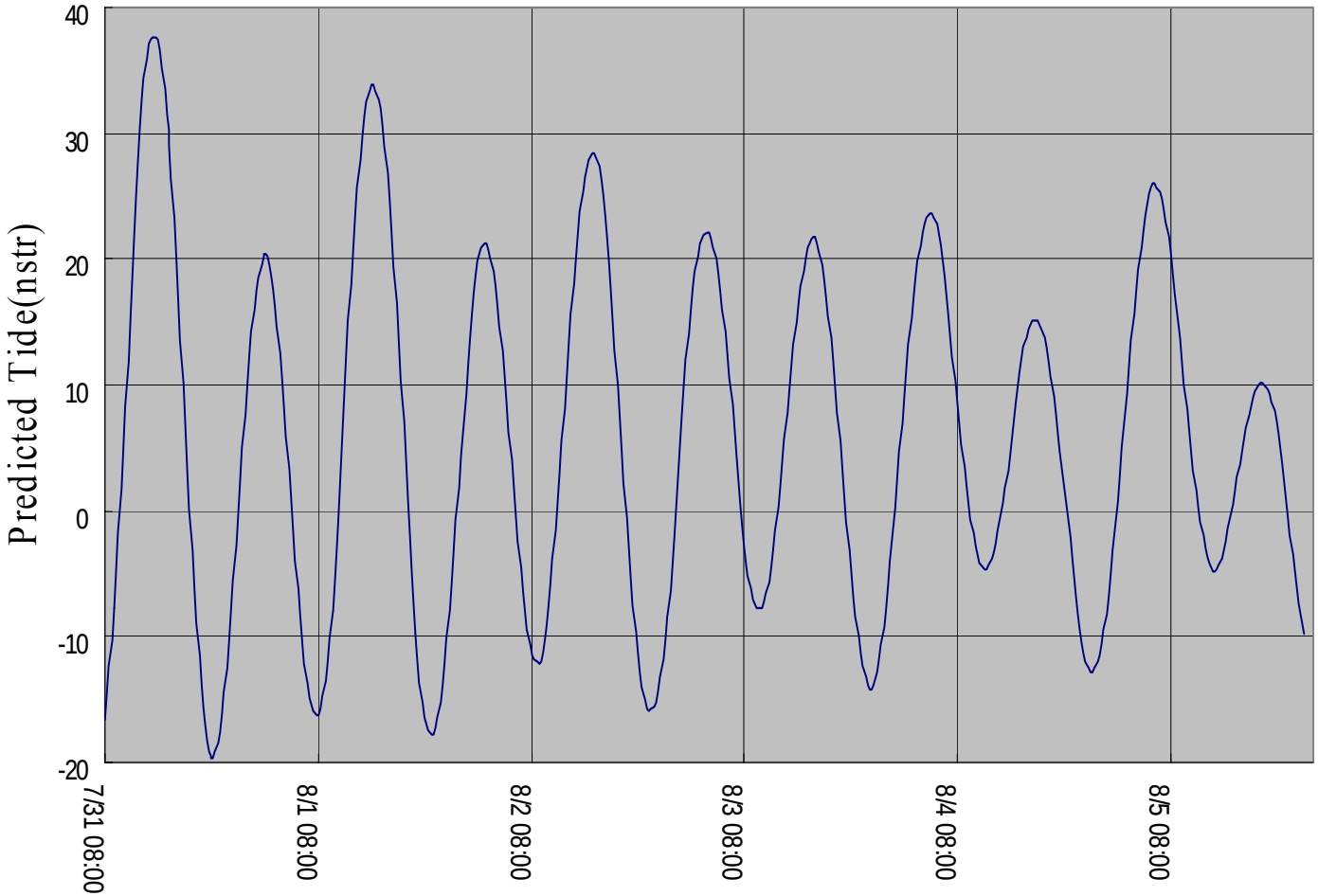
Spectrum of Tidal Potential

(Derived from ETERNA Program)

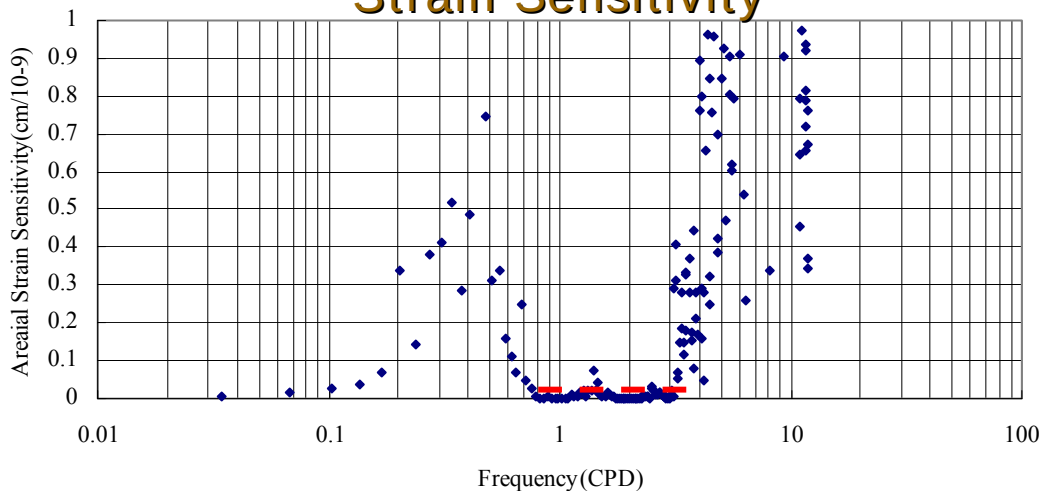


Tidal Potential Series of Observation

(Derived from ETERNA Program)

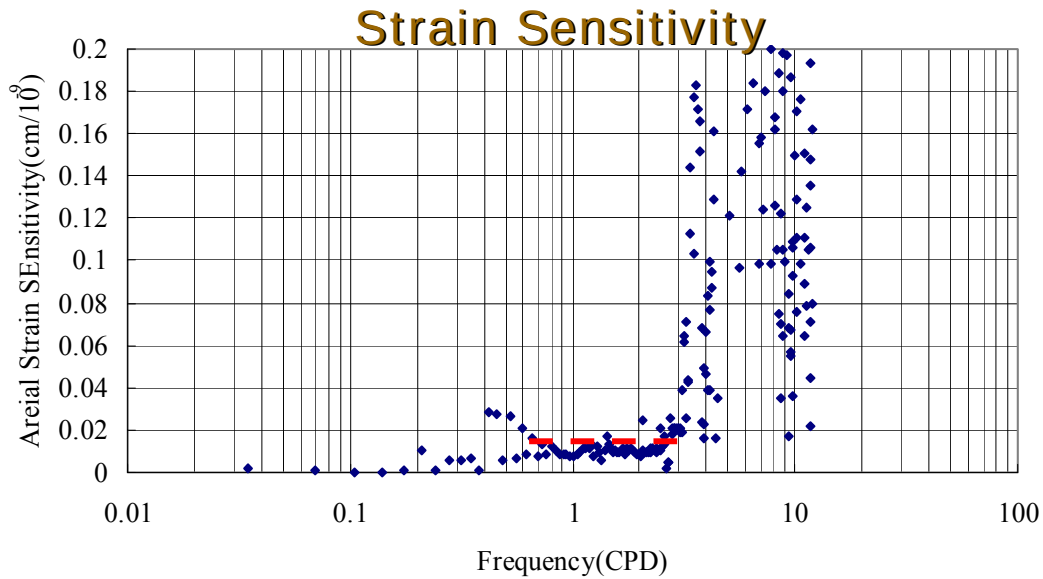


Transfer Function of Tidal Component (Responses to Volumetric Strain)



Liujia(3)
Nov. 2002

0.02 cm/ ppb
≈200 cm/ppm



Naba(3)
Nov. 2002

0.01 cm/ ppb
≈100 cm/ppm

Strain Sensitivity Estimation

Observation	M2 Amp.(cm)	Strain Sensitivity
HUL	0.771*	~ 77 cm/ ppm
TWN	0.401	~ 40 cm / ppm
NBA	0.419	~ 42 cm / ppm
LUJ	0.256	~ 26 cm / ppm
HRD	0.429**	~ 43 cm / ppm
DHR	0.507	~ 51 cm / ppm
TLO	0.336	~ 34 cm / ppm
SIP	0.480	~ 48 cm / ppm

* Effected by ocean tide **Effected by pumping

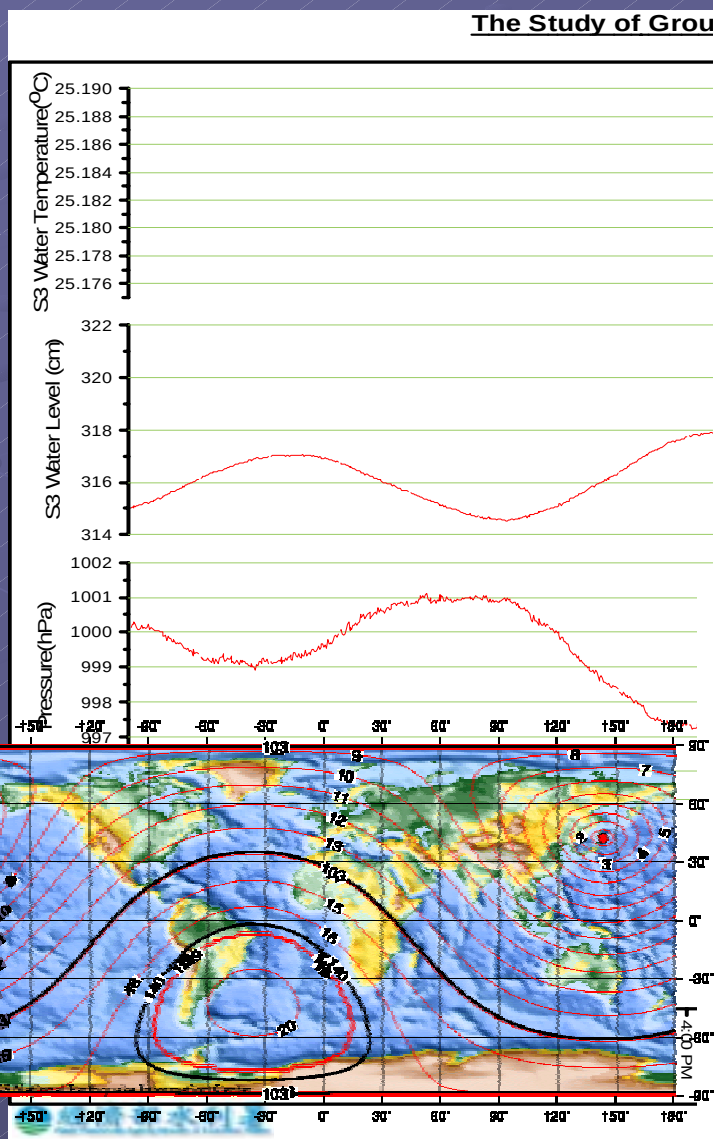
Observation Results

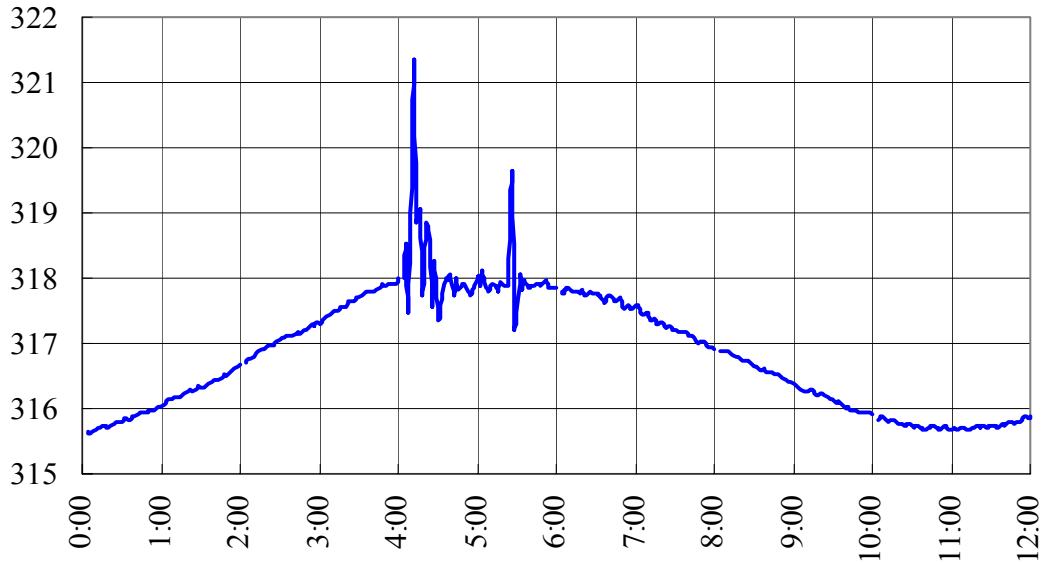
Earthquake	observation	HUL	TWN	LUJ	NBA	HDN	DHR	TLO	SIP
2003/4/3 Taina, M=4.96	2			S	S				
2003/6/10 Taitung, M=6.5	3			S	O		O+S		O
2003/6/17 Taitung, M=5.9	2				O				O
2003/12/10 Taitung, M=6.6	7	O+S	O+S	S	B	S	O+S	O+S	O
2003/12/11Taitung, M=5.7	1				S				
2003/12/18 Taitung, M=5.78	1	O							
2004/1/1Taitung, M=5.9	1	O				O			
2004/1/6 Ilan, M=4.63	1		O+S	O					
2004/1/13 Hulien, M=5.0	1	S		O					
2004/2/4 Hulien, M=6.0	3	O+S	O+S					O	
2004/2/9 Hulien, M=4.3	2	O					S		
2004/4/20 Taitung, M=5.1	1	O							
2004/4/24 Hulien, M=5.3	1	O						O	
2004/4/25 Hulien, M=4.31	1	O							
2004/5/1Hulienm, M=5.8	3	S	S	S				O+S	
2004/5/8 Taitung, M=5.7	4	O		S			O	O	
2004/5/16Taitung, M=6.0	1	O		S					
2004/5/19 Taitung, M=6.5	6	S	O+S	S			S	S	O
2004/7/6 Ilan, M=5.8	1		S				S		

O: oscillation S: step-like change blank: no deteact

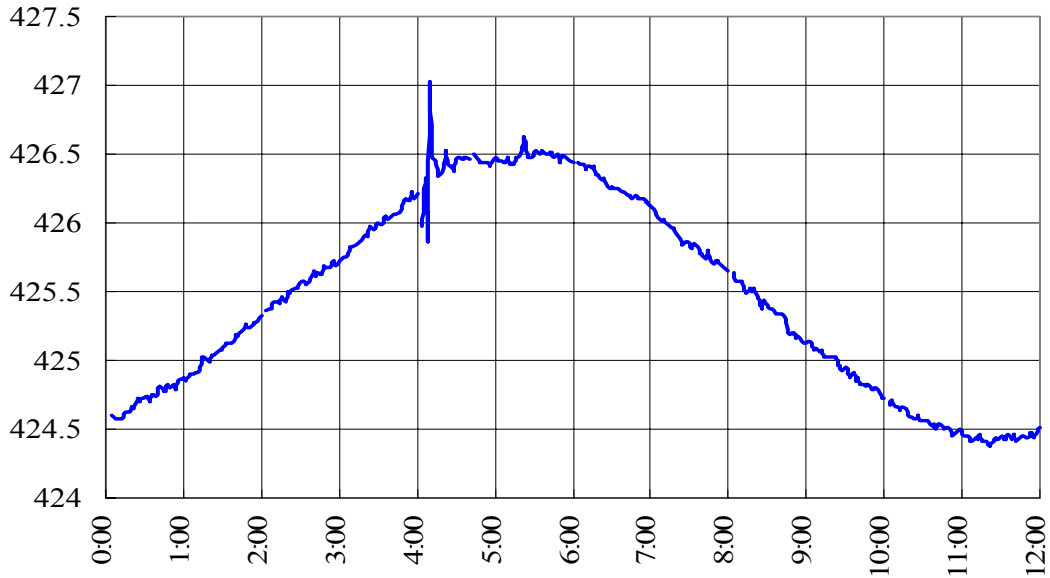
Total 102 observations

Types of the Coseismic Responses: Oscillation

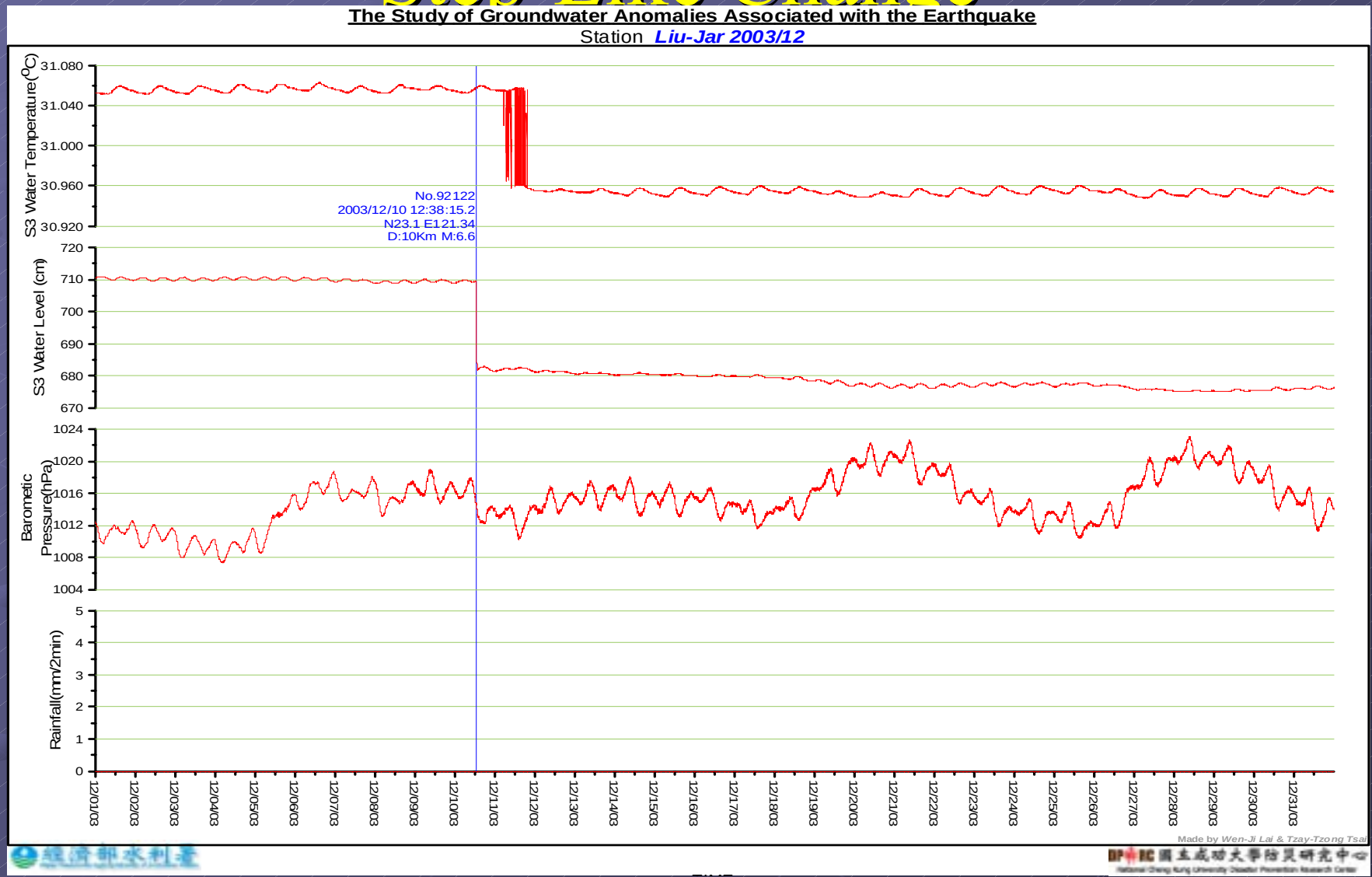




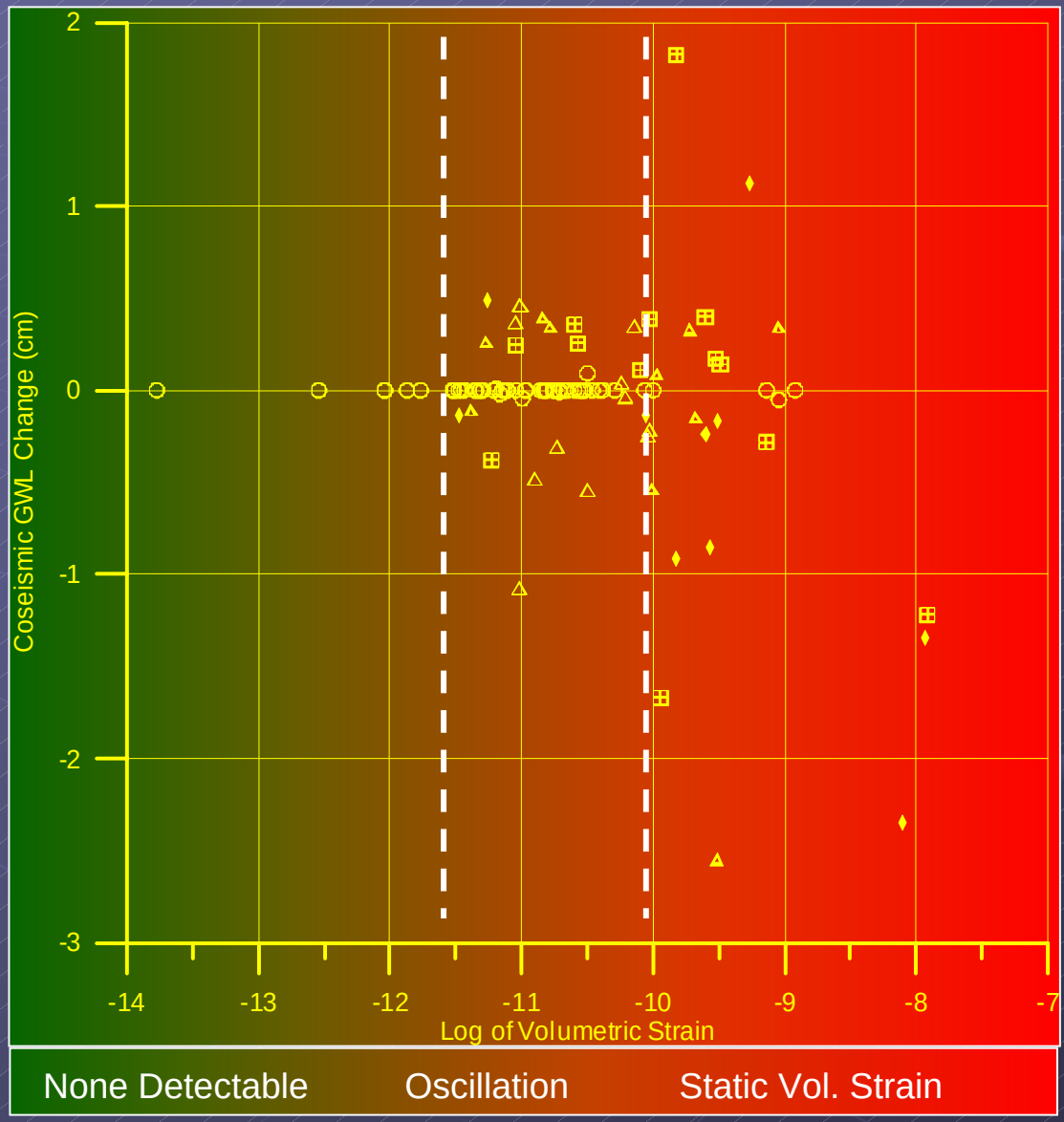
92/9/26



Types of the Coseismic Responses: Step-Like Change



Coseismic and Volumetric Strain

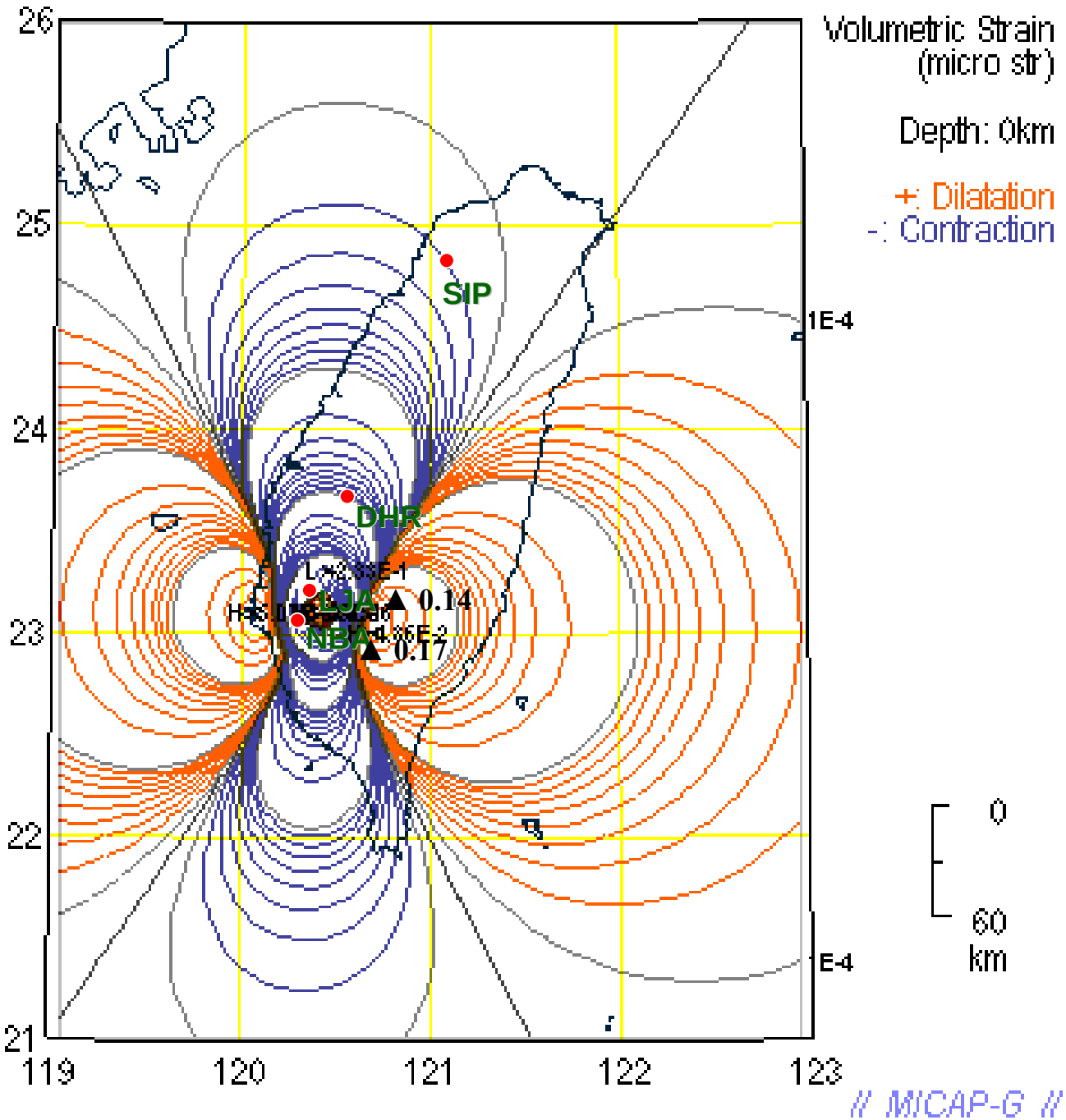


2003~2004 May
Mw> 5
Total 102 Observation
No Detect: 56
Oscillation: 21
Oscillation and Step Change: 10
Step Change: 15

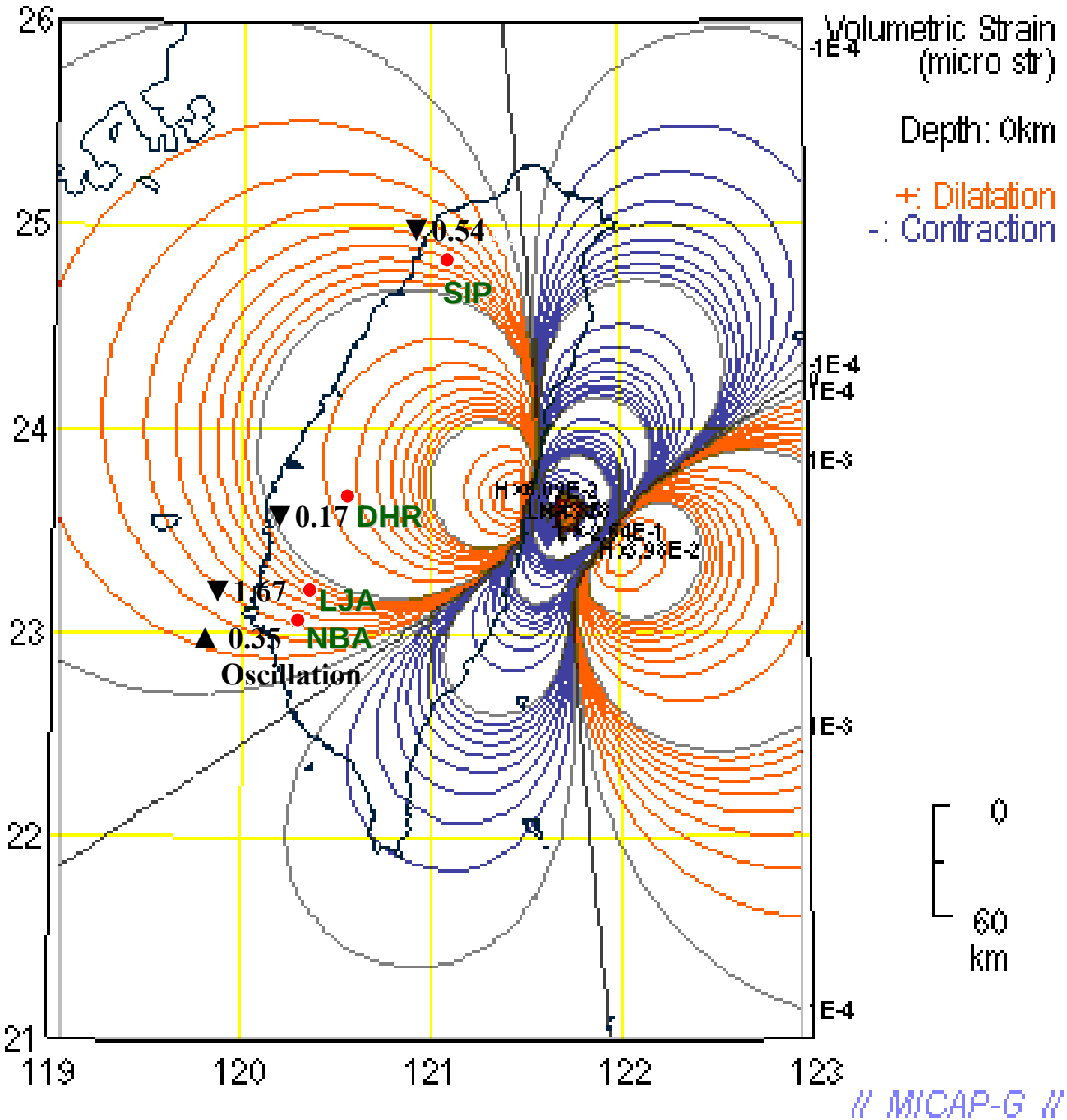
Legend

- None Detectable
- Oscillation
- Oscillation and Step Change
- Step Change

EQ 2003/4/3
Chiayi M 5.0

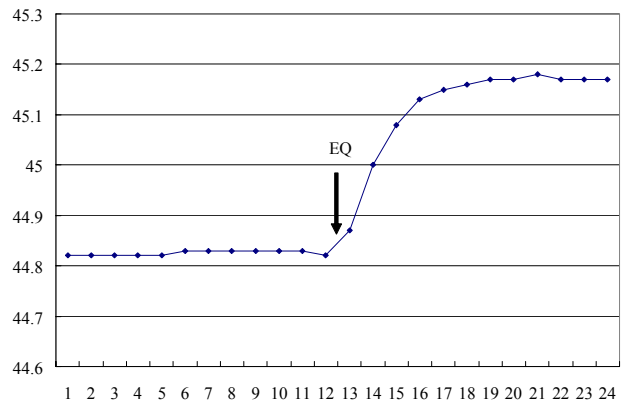


EQ 2003/6/10
Hulien M 6.5

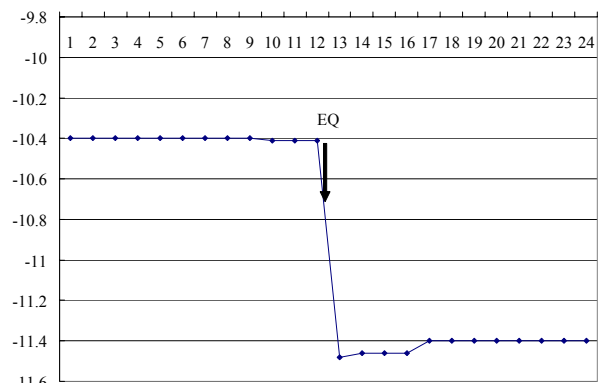


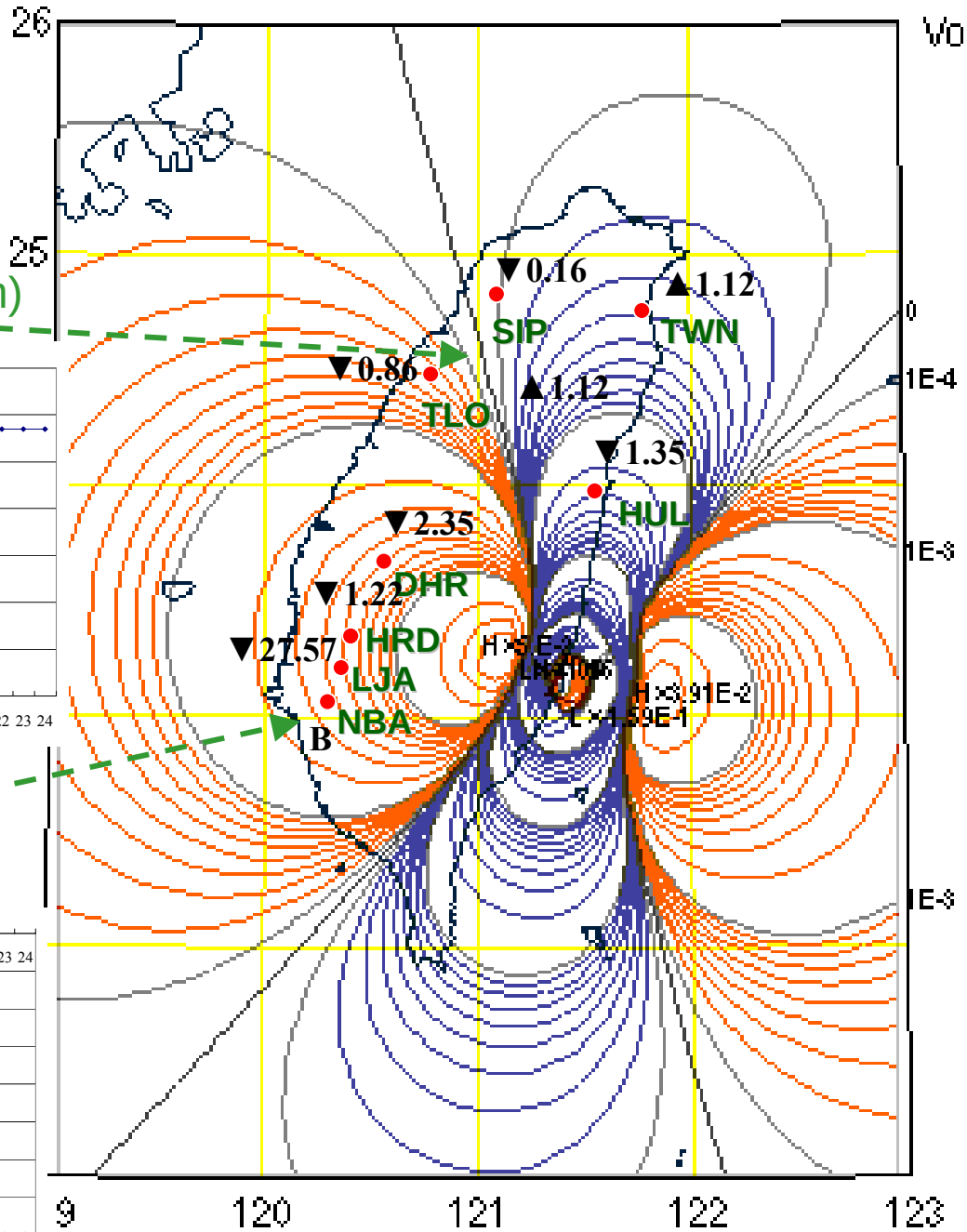
EQ 2003/12/10 Taitung M 6.6

2 wells increase in Miaoli area (6cm~35 cm)



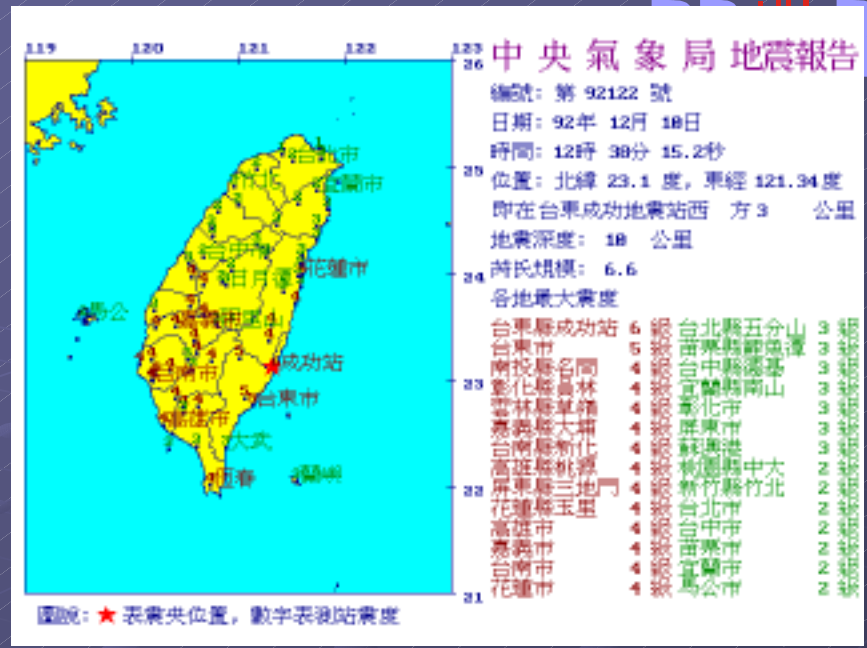
21 Wells decrease in Tainan-Kaoshiung Area (3~107 cm)

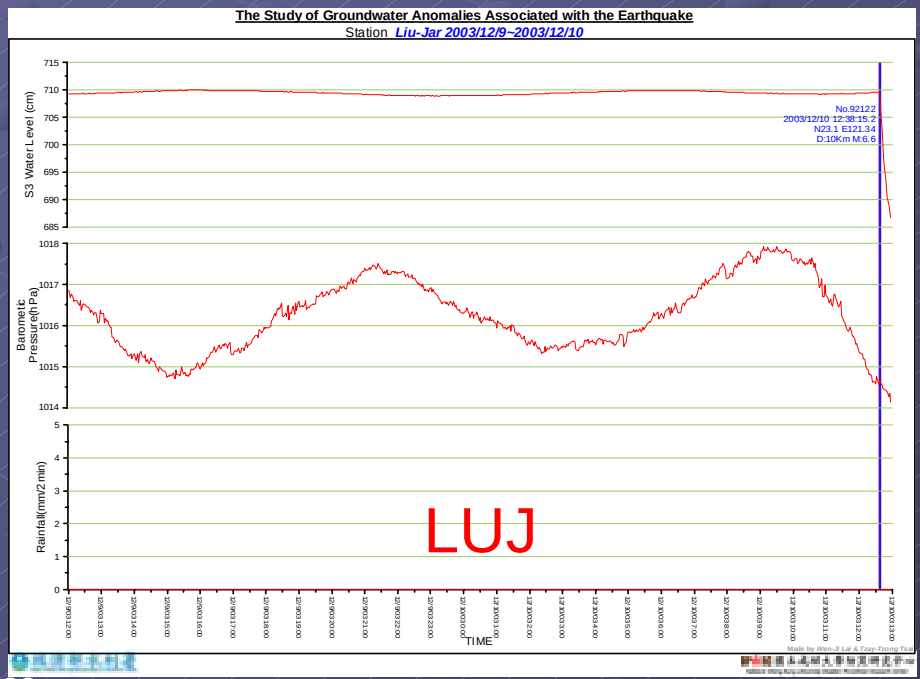


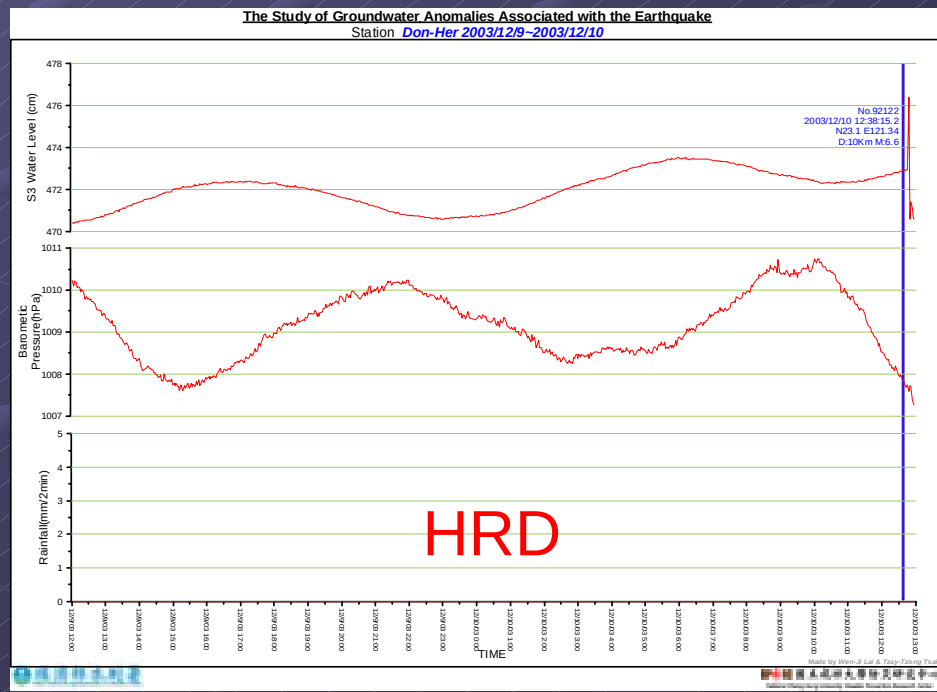


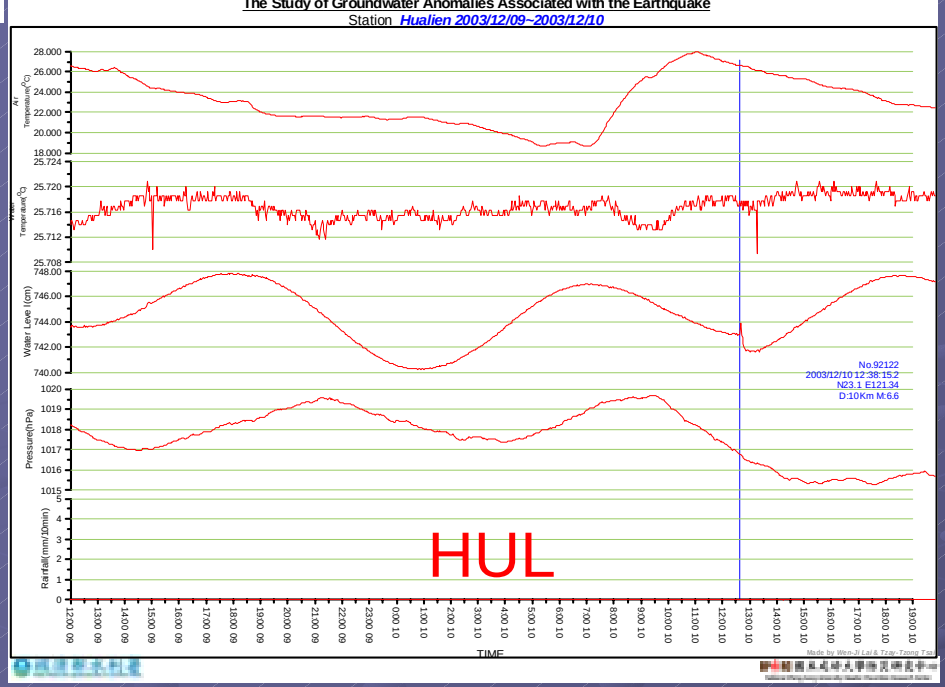
// MICAP-G //

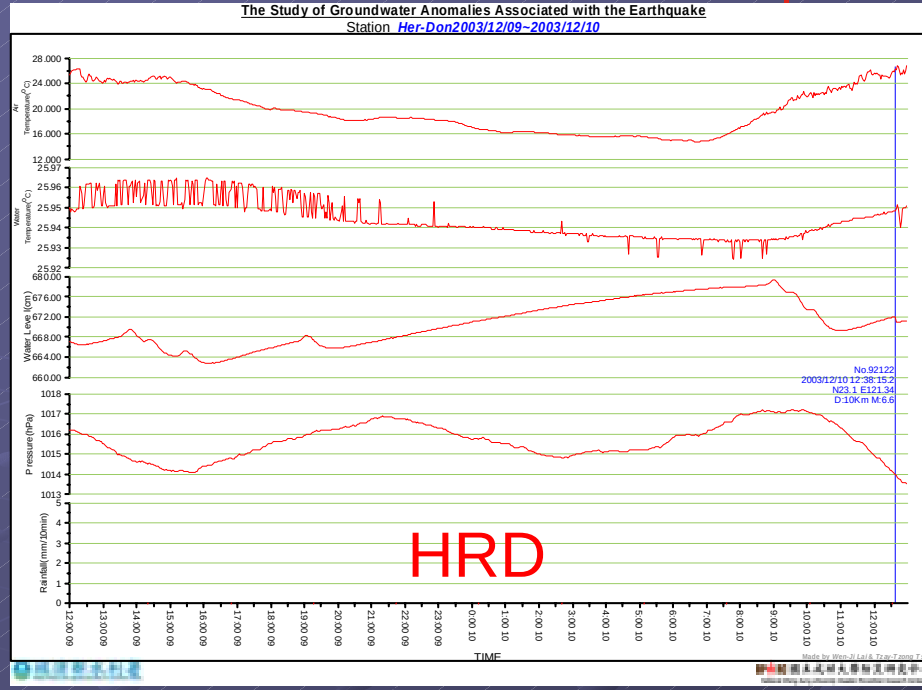
Coseismic GWL Changes in Observation Wells 2003/12/10 Taitung M 6.6

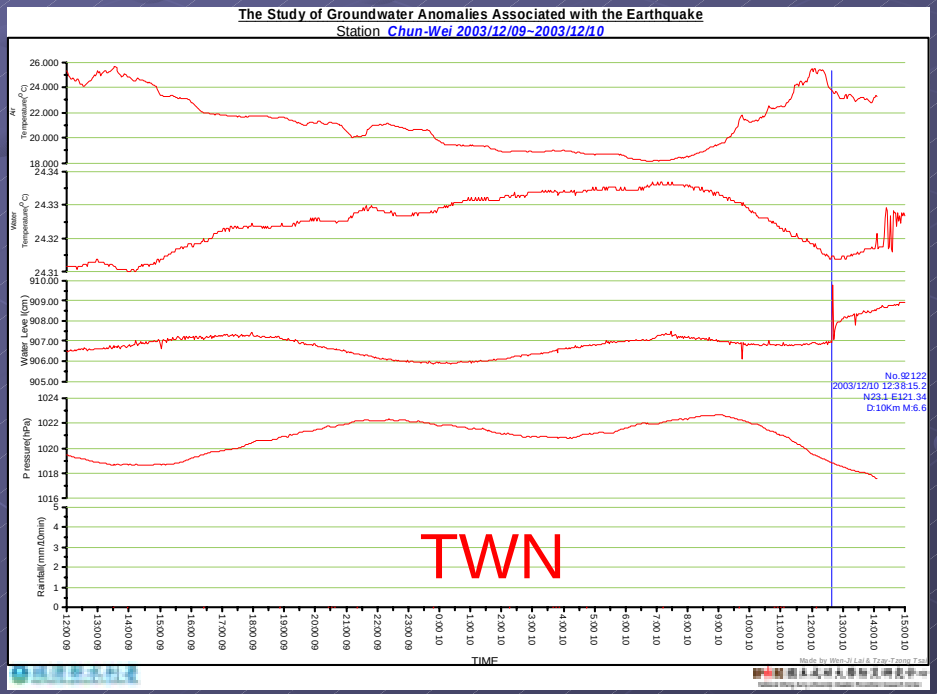


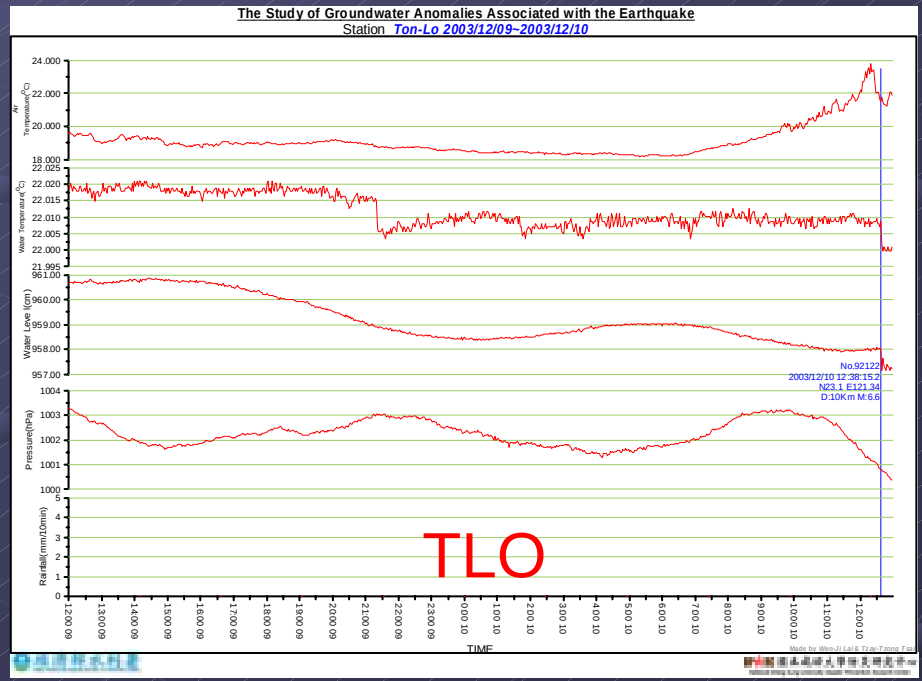




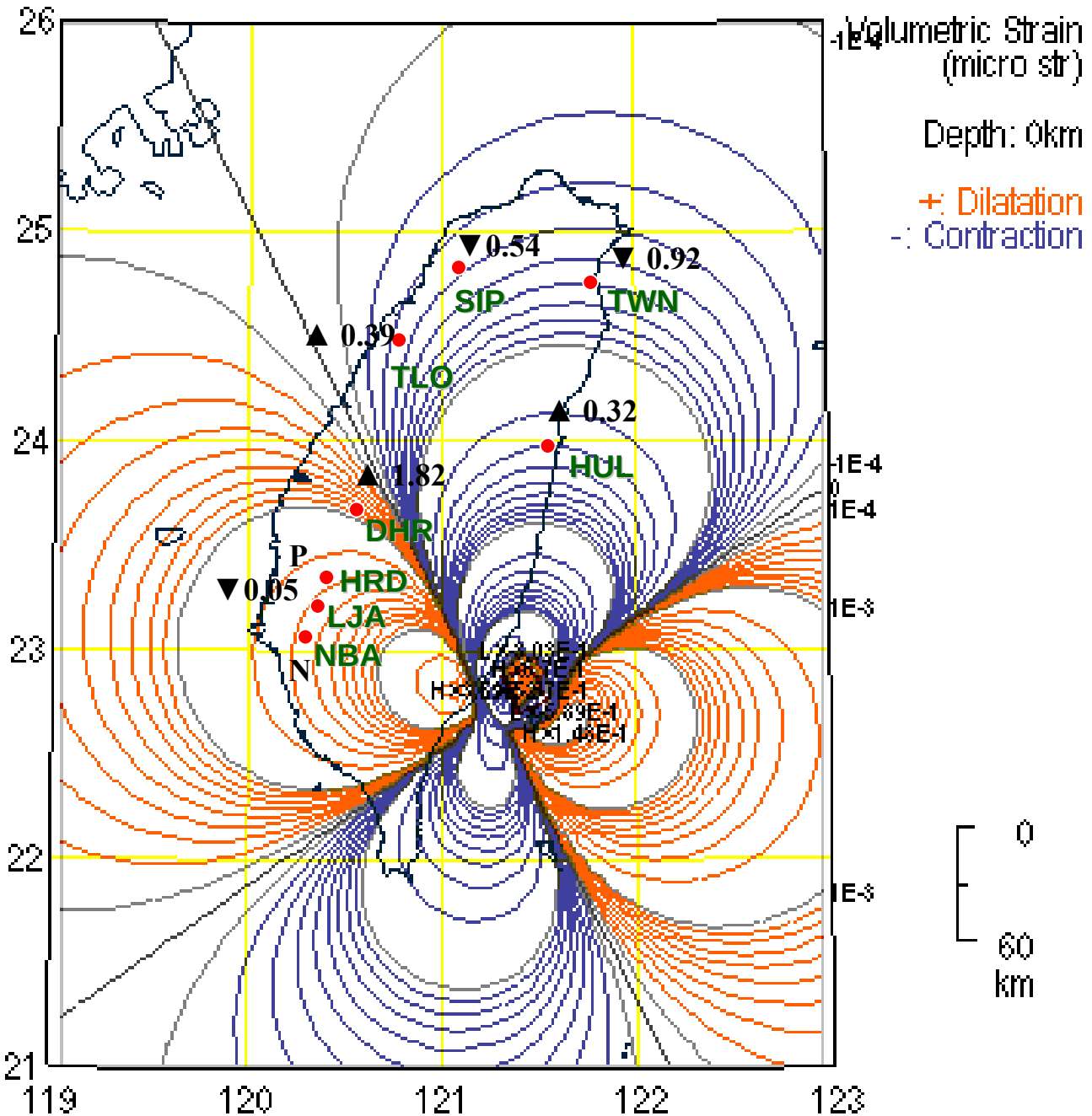

The Study of Groundwater Anomalies Associated with the Earthquake
Station Hualien 2003/12/09~2003/12/10
Air Temperature(°C)
Water Temperature(°C)
Water Leve l(cm)
Pressure(hPa)
Rainfall(mm/10min)
No.92122
2003/12/10 12:38:15.2
N23.1 E121.34
D:10Km M:6.6
HUL
TIME


The Study of Groundwater Anomalies Associated with the Earthquake
Station Her-Don2003/12/09~2003/12/10
Air Temperature(°C)
Water Temperature(°C)
Water Leve l(cm)
Pressure(hPa)
Rainfall(mm/10min)
No.92122
2003/12/10 12:38:15.2
N23.1 E121.34
D:10Km M:6.6
HRD
TIME


The Study of Groundwater Anomalies Associated with the Earthquake
Station Chun-Wei 2003/12/09~2003/12/10
Air Temperature(°C)
Water Temperature(°C)
Water Leve l(cm)
Pressure(hPa)
Rainfall(mm/10min)
No.92122
2003/12/10 12:38:15.2
N23.1 E121.34
D:10Km M:6.6
TWN
TIME

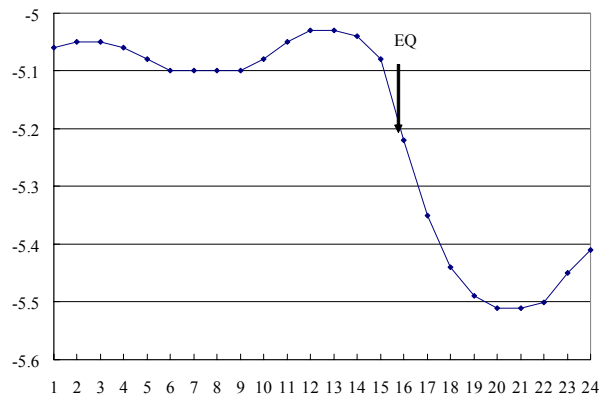

The Study of Groundwater Anomalies Associated with the Earthquake
Station Ton-Lo 2003/12/09~2003/12/10
Air Temperature(°C)
Water Temperature(°C)
Water Leve l(cm)
Pressure(hPa)
Rainfall(mm/10min)
No.92122
2003/12/10 12:38:15.2
N23.1 E121.34
D:10Km M:6.6
TLO
TIME

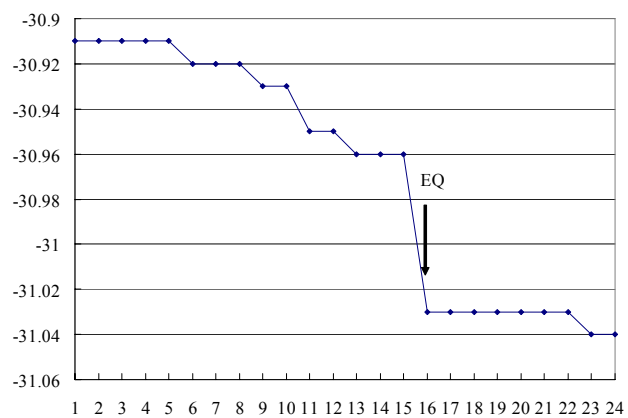
EQ 2004/5/19
Taitung M 6.5
Model I

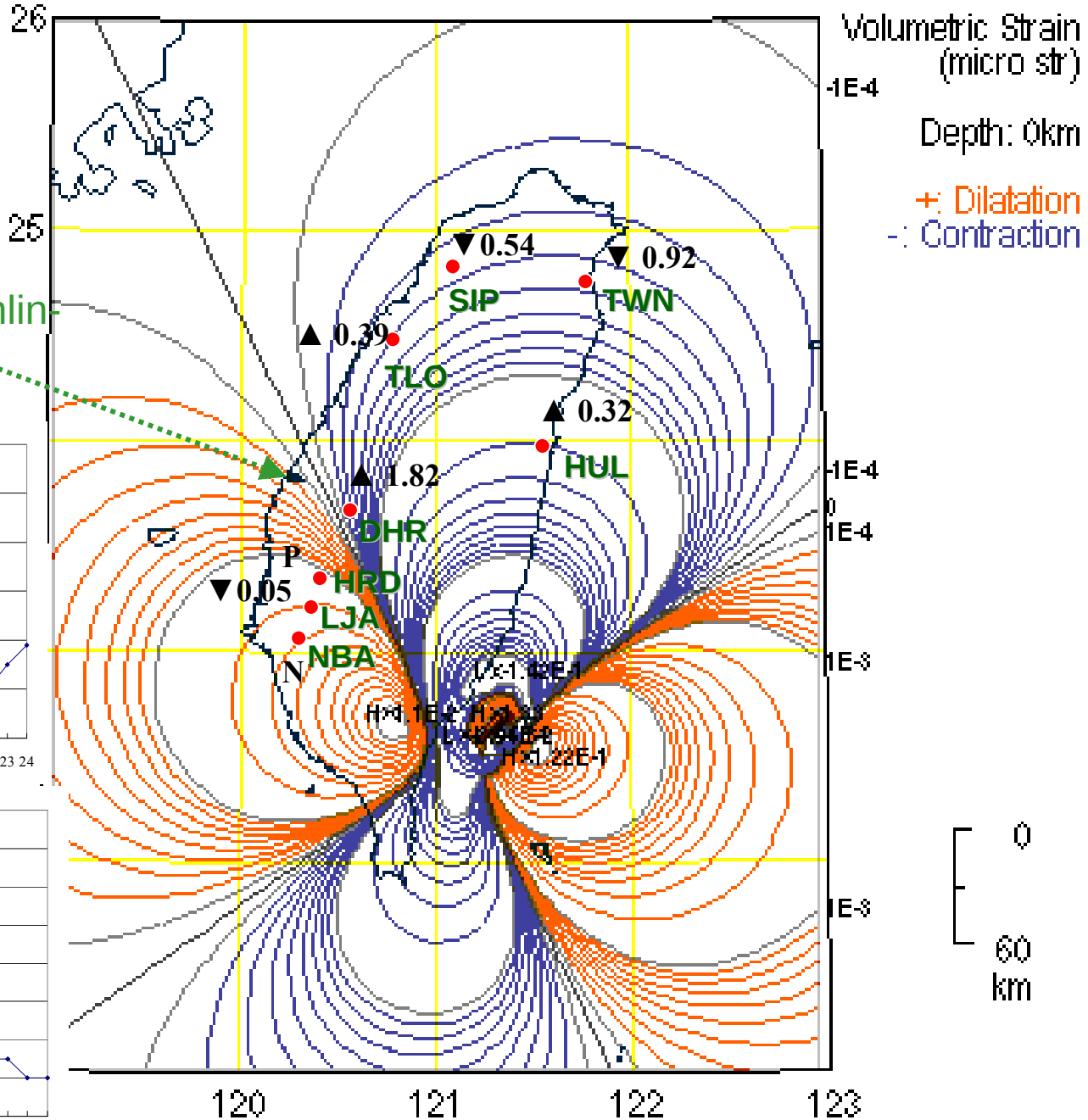


EQ 2004/5/19 Taitung M 6.5 Model II

6 Wells decrease in Yunlin-Chiayi Area







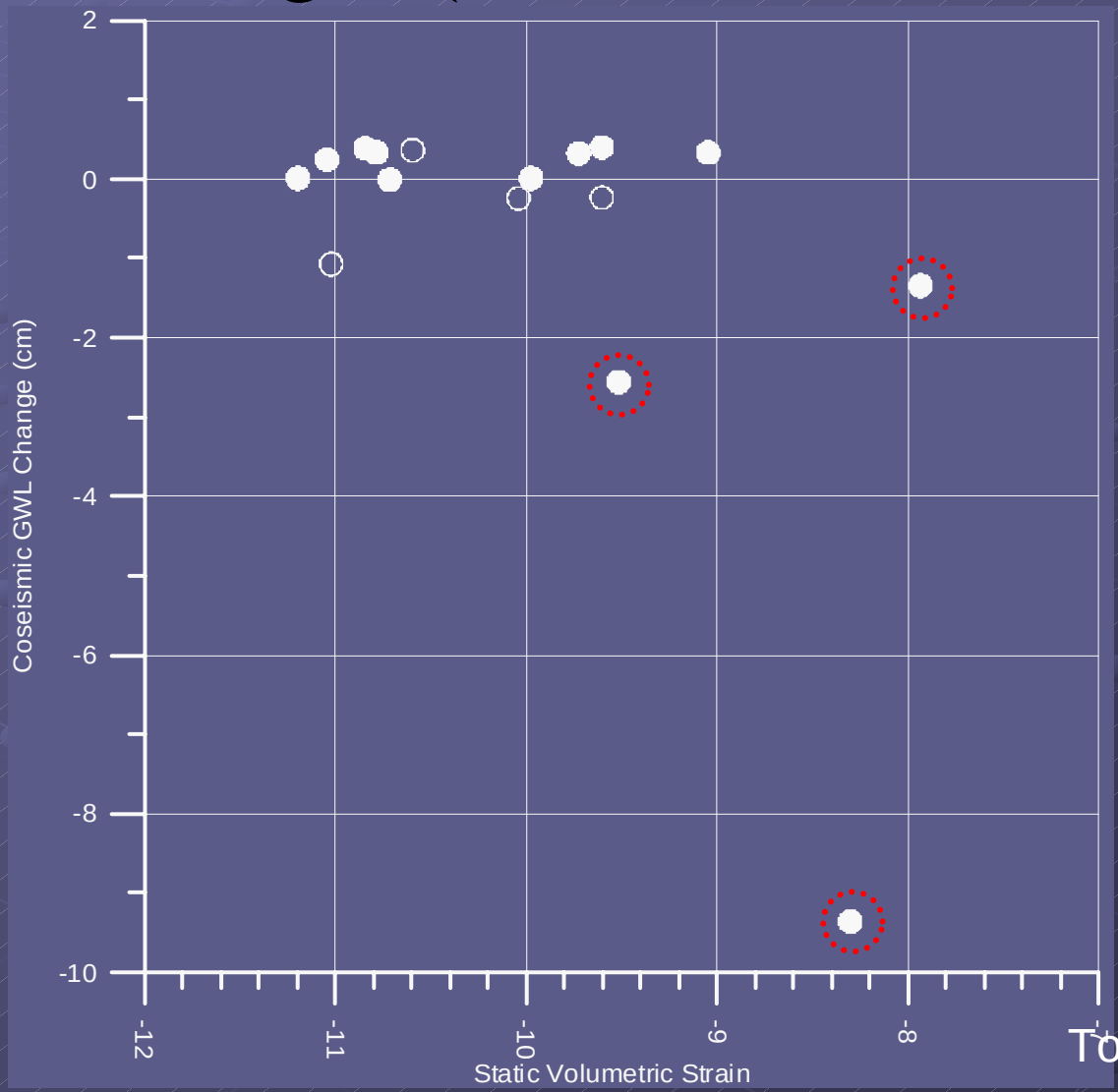
Discussion

- Coseismic response had two kinds different responses (Local/ Distant event).
- Why there so large difference between predicted value and observation ?
- Curiously Observation
- Possible Mechanism

Comparison of the coseismic Groundwater Level Changes (Observation: Hulien)

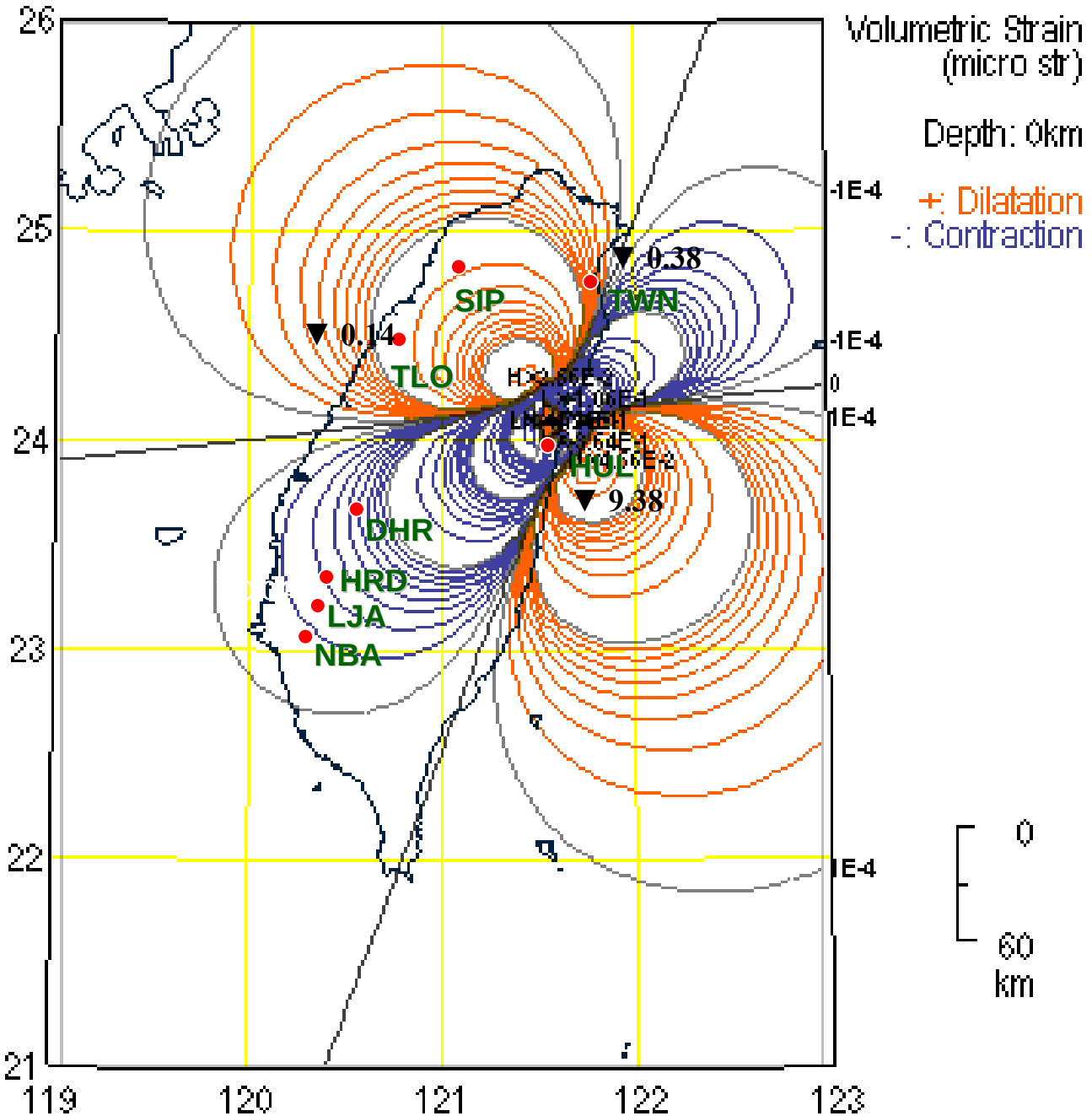
Earthquake	Vol. Strain	Pred. GWL Chg.	Observation	Type
2003/12/10 Taitung, M=6.6	-1.16E-08	8.91983	-1.3471	O+S
2003/12/11Taitung, M=5.7	-1.93E-11	0.00297		n
2003/12/18 Taitung, M=5.78	-1.64E-11	0.00252	0.3313	O
2004/1/1Taitung, M=5.9	-3.05E-10	0.04692	-2.5588	S
2004/1/6 Ilan, M=4.63	-2.49E-10	0.03832	0.3989	O
2004/1/13 Hulien, M=5.0	-1.06E-10	0.01628		n
2004/2/4 Hulien, M=6.0	2.49E-10	-0.03829	-0.2362	O+S
2004/2/9 Hulien, M=4.3	9.52E-12	-0.00147	-1.0751	O
2004/4/20 Taitung, M=5.1	9.12E-11	-0.01404	-0.2438	O
2004/4/24 Hulien, M=5.3	-8.98E-10	0.13830	0.3306	O
2004/4/25 Hulien, M=4.31	-1.44E-11	0.00221	0.3842	O
2004/5/1Hulienm, M=5.8	2.54E-11	-0.00392	0.3602	O
2004/5/8 Taitung, M=5.7	-1.88E-10	0.02898	0.3200	S
2004/5/16Taitung, M=6.0	-4.98E-09	0.76698	-9.3588	S
2004/5/19 Taitung, M=6.5	-9.03E-12	0.00139	0.2458	O
2004/7/6 Ilan, M=5.8	-6.38E-12	0.00098		n

Comparison of the coseismic Groundwater Level Changes (Observation: Hulien)

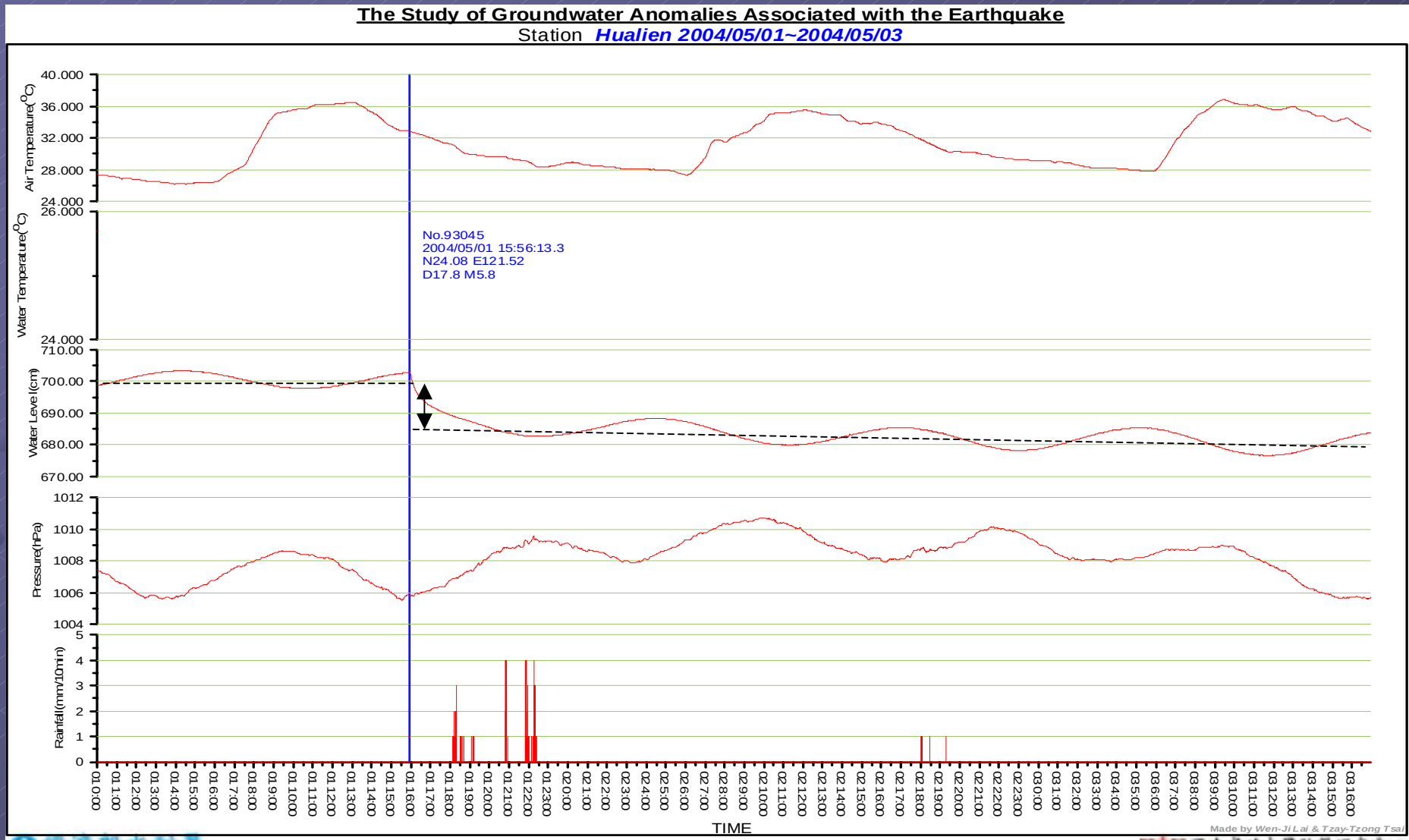


Total 16 observation

EQ 2004/5/1
Hulien M 5.8

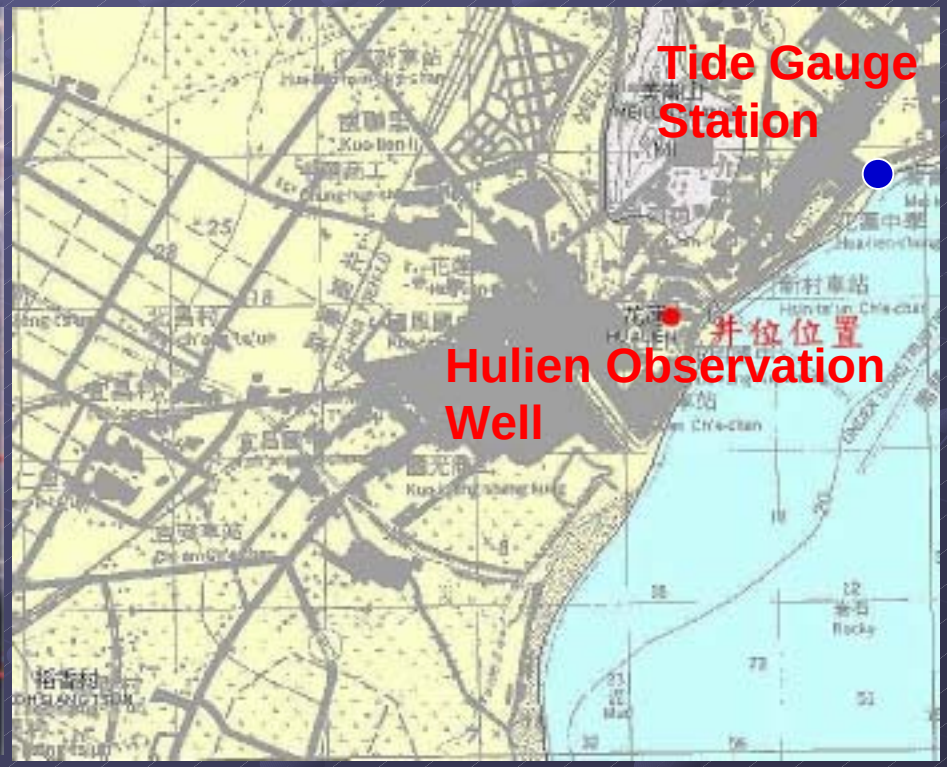


Post-seismic Response of GWL Changes



Location of Hulien Observation Well

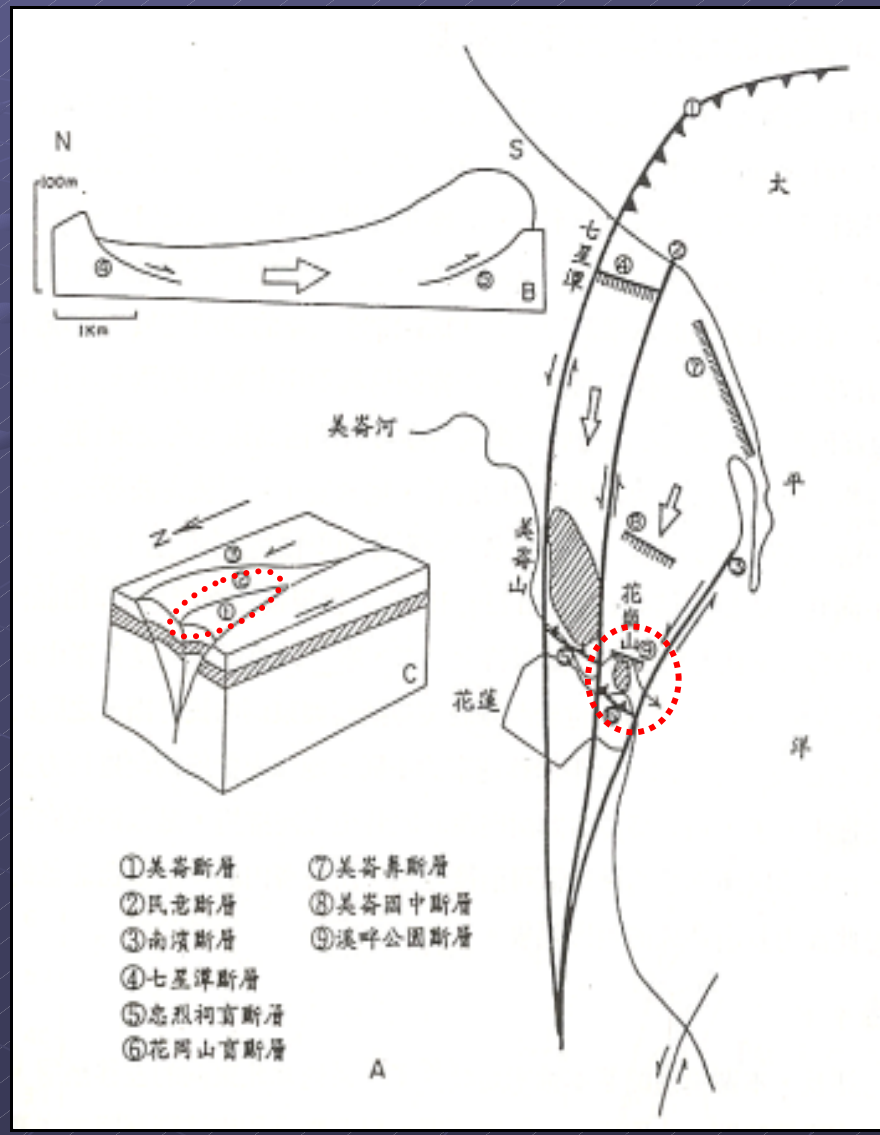
200 km



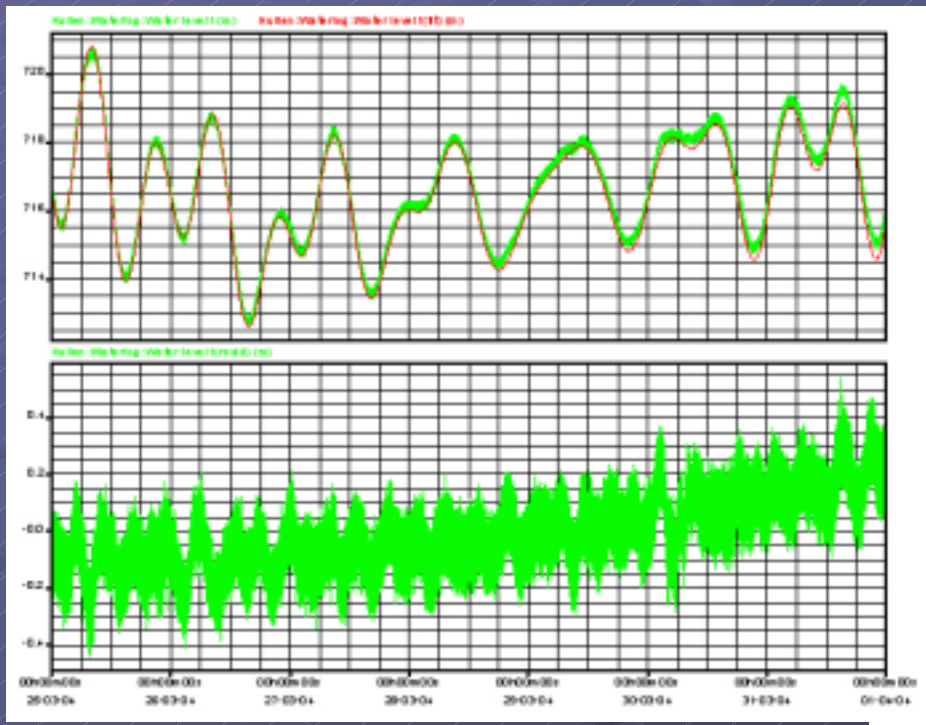
1 km

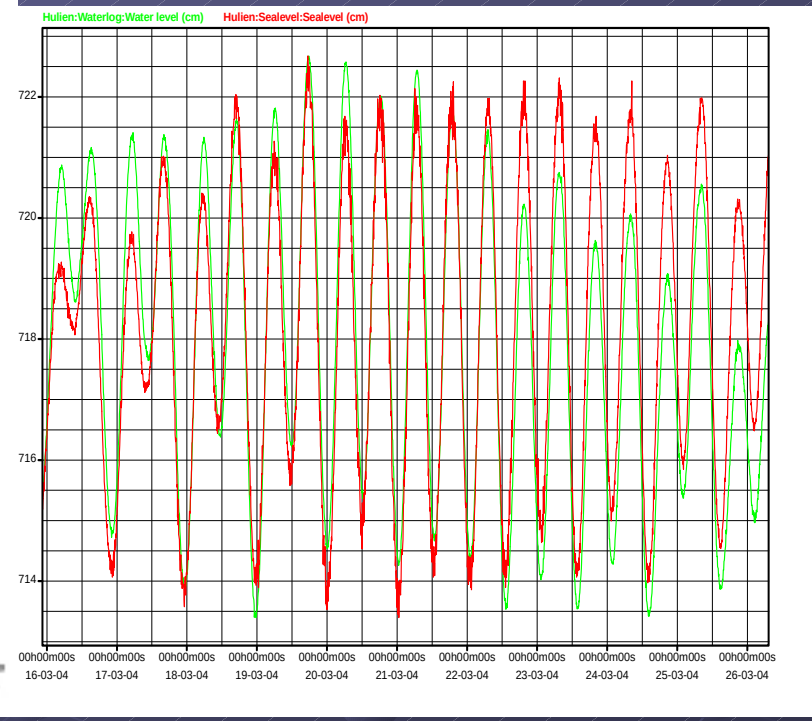
Possible Mechanism of Observation in Hulien Observation Well

- Local geological structure environment
- Observation well located on fault zone
- Locally pull-apart setting will made the difference response with the predicted crust volumetric strain



Comparison of Ocean Tide and Groundwater Level Observation



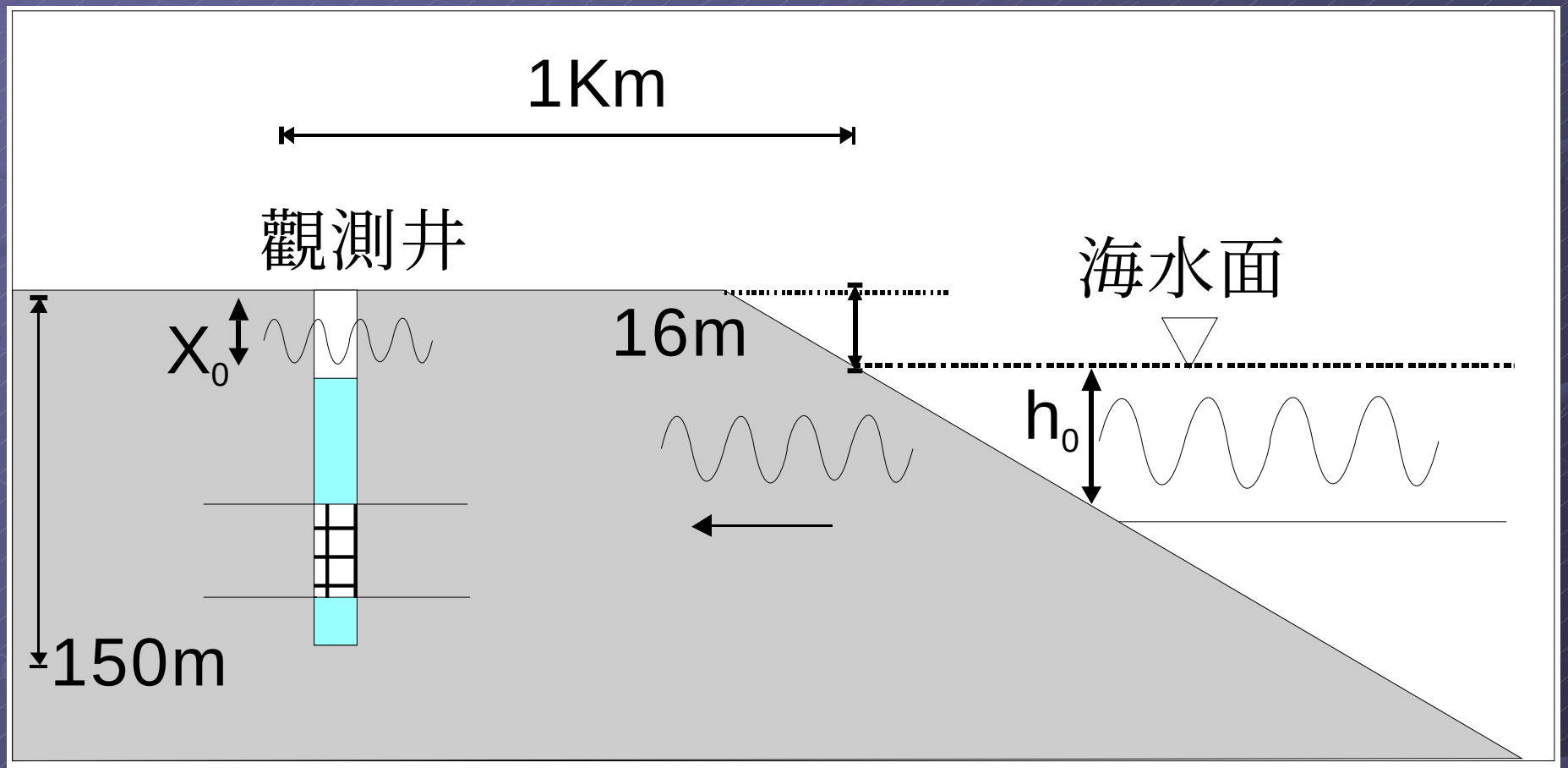


Red: Ocean tide observation in Huilen Harbor (6 min)

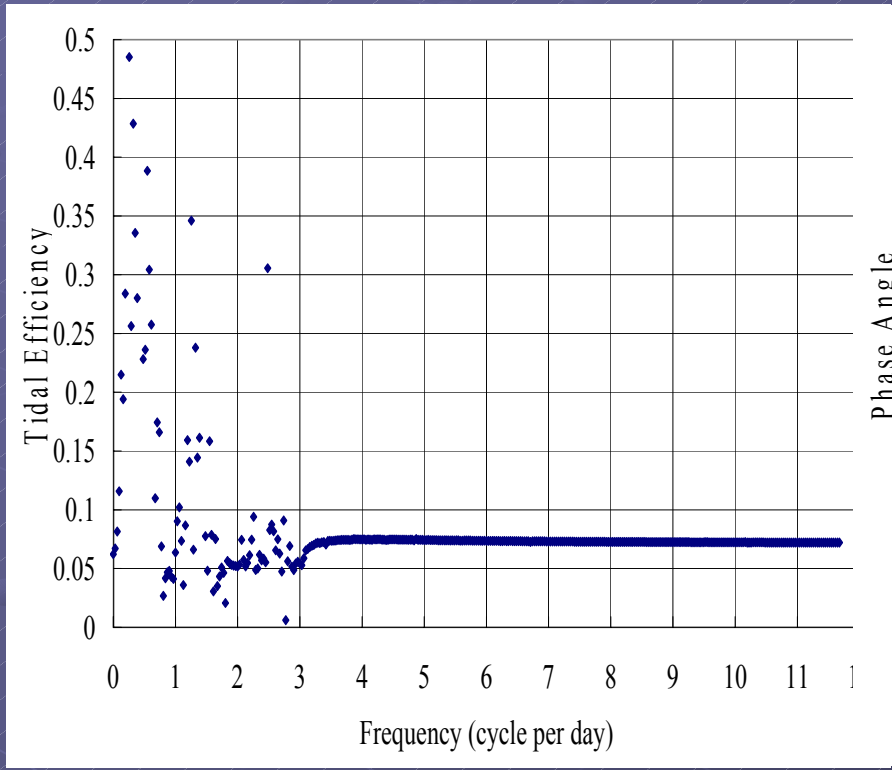
Green: Groundwater level observation in Huilen Observation(2 min)

Possible Mechanism of Observation in Hulien Observation Well

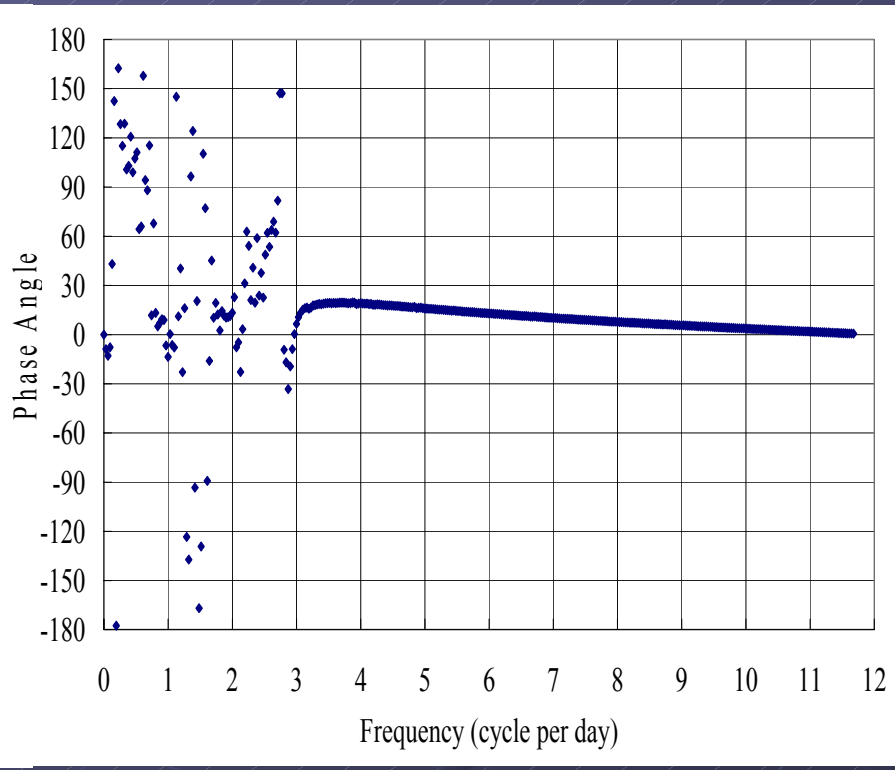
- Ocean Dynamic Loading Changes



Spectra of ocean water loading to Huilen Observation Well

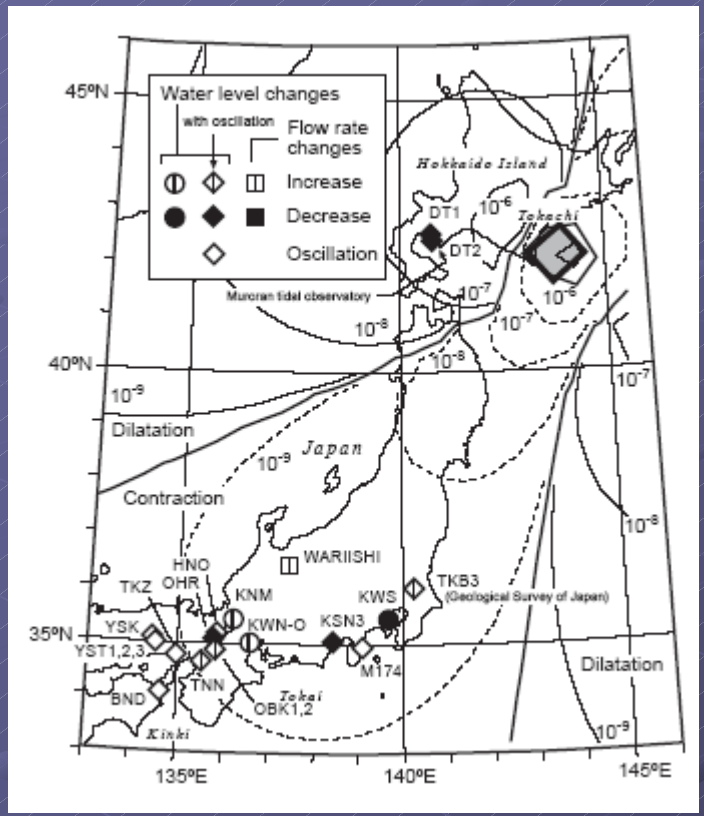


(a) Amplitude

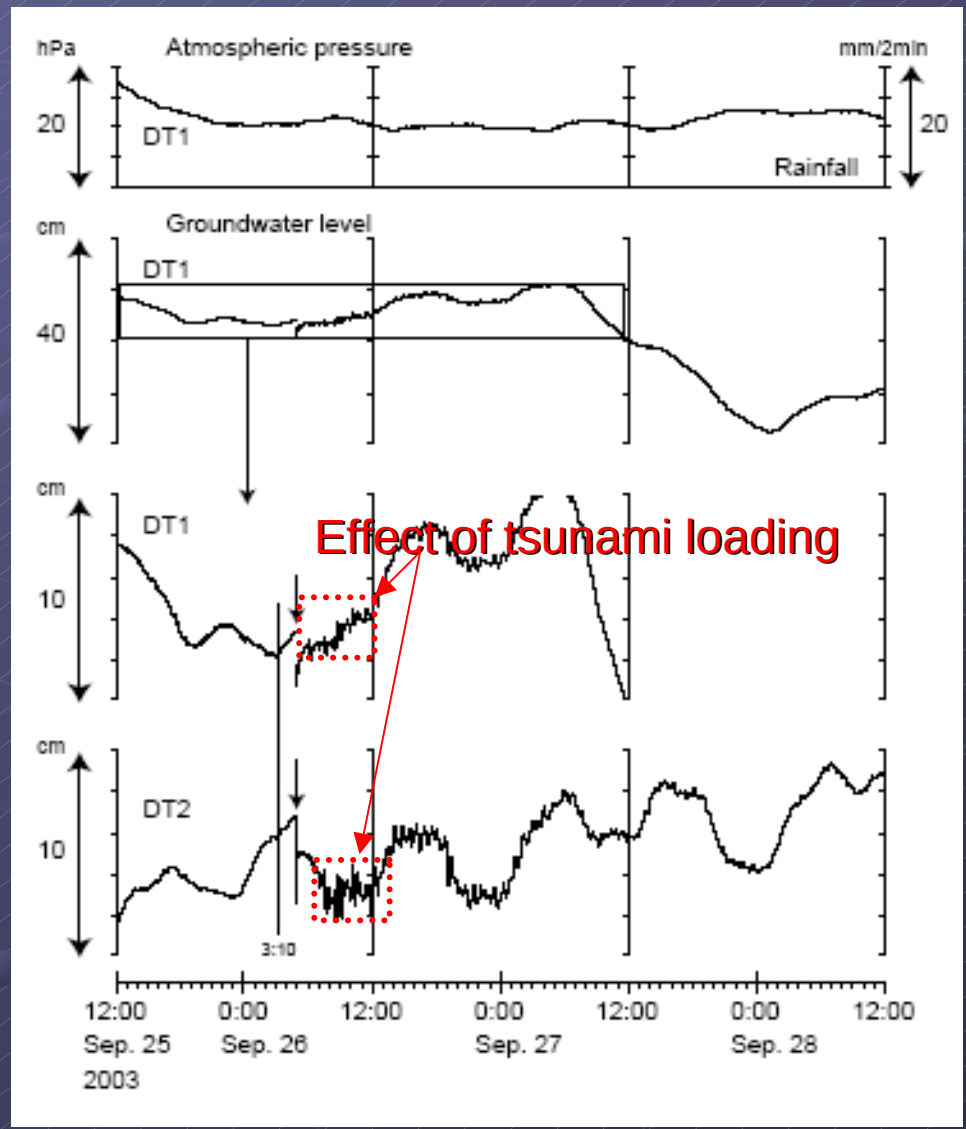


(b) Phase Angle

Post-seismic Response of GWL Changes



Sato et al., (2004)



Summary

- The mechanism of coseismic GWL changes should consider the spatial difference of the response
- Most of local observation responses to volumetric strain induced by dislocation, but easily been attenuate .
- Pressure head increase made by seismic shacking are most common phenomenon of distant observation
- The characteristic of alluvial sediment could be the main reason effect the coseismic changes
- The ocean loading could be a possible mechanism of coseismic or post seismic GWL changes