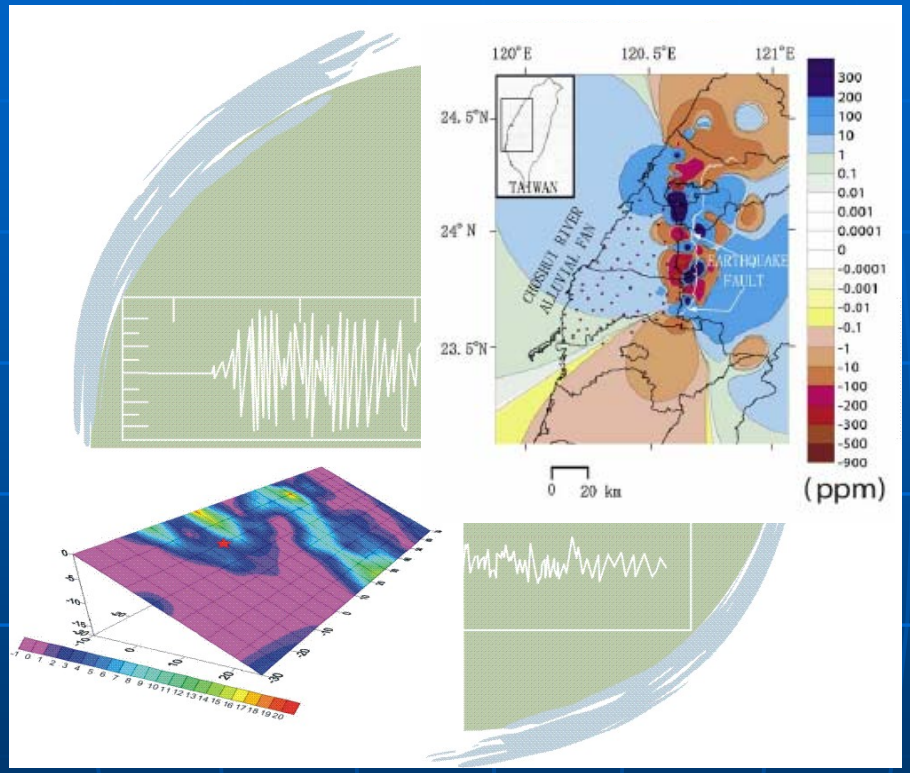
An overview on the results of the study of groundwater anomalies associated with the earthquake in Taiwan, 2001~2005



Chjeng-Lun Shieh[1,2], Wen-Chi Lai[1], Chung-Min Tseng[3], Chi-Cheng Yang[3]

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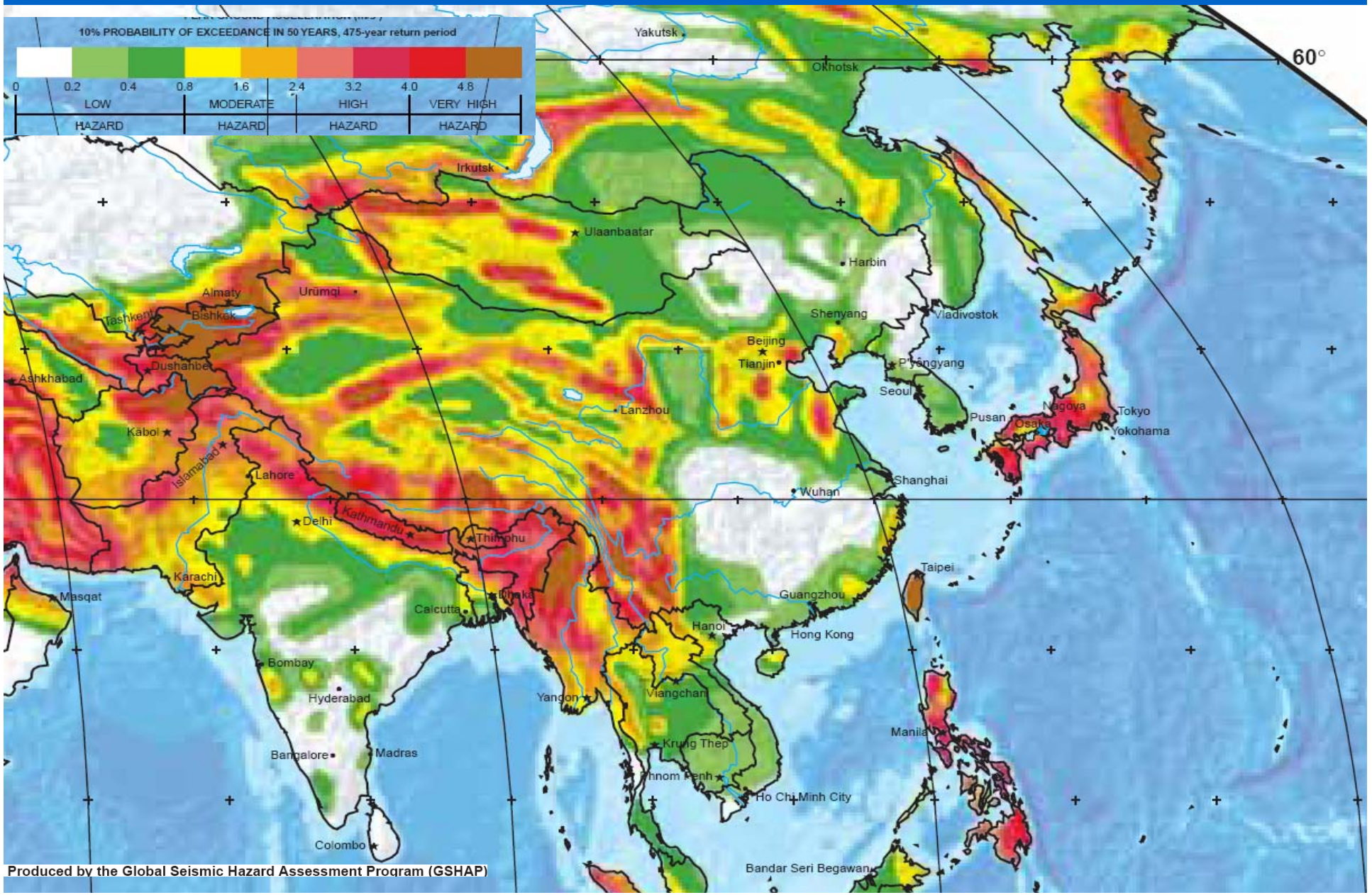
2. Department of Hydraulic and Ocean Engineering, National Cheng Kung University, Taiwan
3. Water Resource Agency, Ministry of Economic Affair, Taiwan

DPRC

Introduction: GLOBAL SEISMIC HAZARD MAP



Deadliest Earthquakes (1990~2004)

Year	Date	Magnitude	Fatalities	Region
2004	12/26	9.0	283,106	Off West Coast of Northern Sumatra
2003	12/26	6.6	31,000	Southeastern Iran
2002	03/25	6.1	1,000	Hindu Kush Region, Afghanistan
2001	01/26	7.7	20,023	India
2000	06/04	7.9	103	Southern Sumatera, Indonesia
1999	09/21	7.7	2297	Central Taiwan
1999	08/17	7.6	17,118	Turkey
1998	05/30	6.6	4,000	Afghanistan-Tajikistan Border Region
1997	05/10	7.3	1,572	Northern Iran
1996	02/03	6.6	322	Yunnan, China
1995	01/16	6.9	5,530	Kobe, Japan
1994	06/20	6.8	795	Colombia
1993	09/29	6.2	9,748	India
1992	12/12	7.8	2,519	Flores Region, Indonesia
1991	10/19	6.8	2,000	Northern India
1990	06/20	7.4	50,000	Iran

Origin: USGS Database

Annual Seismicsity of Earthquakes in the World for 2000 - 2005

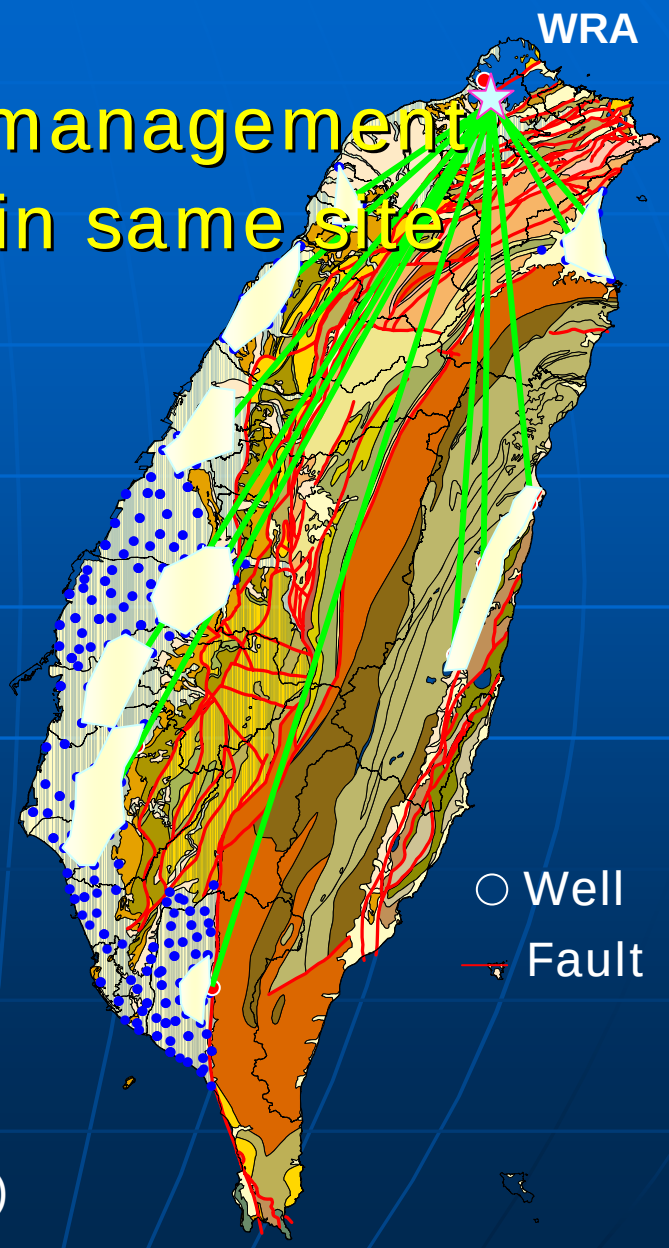
Magnitude	World	Taiwan	Japan	USA
7.0 to 7.9	13	0.33	0.17	1
6.0 to 6.9	134	4	3	5
5.0 to 5.9	1281	34	14	48
4.0 to 4.9	8885	153	87	365
3.0 to 3.9	6437	102*	305	1150
Total	16750	293.33	409.17	1569
Data Period	2000-2005	2000-2005	2000-2005	2000-2005
Data Origin	USGS	CWB	JMA	USGS

Taiwan Groundwater Monitoring Network (1992~2003)

- Design for water resources management
- Monitoring different aquifer in same site

Sub-Province	Site	Well
Taipei Basin	12	30
Taoyuan Tableland	5	10
Hsinchu-Miaoli Area	16	35
Choshui River Alluvial Fan	70	193
Chiayi-Tainan Area	40	105
Pingtung Plain	55	132
Ilan Plain	30	45
Total	228	560

(~2004)



Goals of Our Work

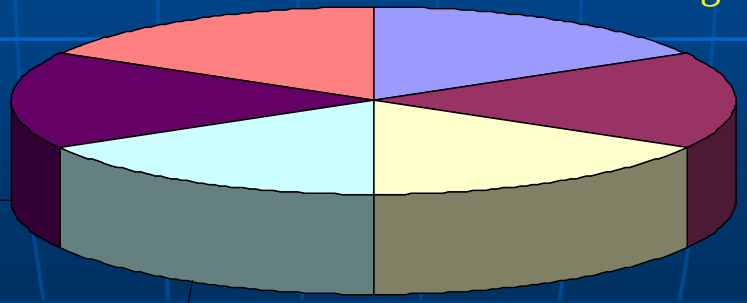
- **Final Goals**
  - Application for earthquake hazard mitigation
  - Cross-Linkage with related projects
- **Directly Goals**
  - Provide good quality observation data
  - Development of needed techniques and researches for long-term monitoring
  - Evaluate the relationship between groundwater changes and earthquake occurrences
  - Extend the functions of “Groundwater Monitoring Networks of Taiwan”

Advantages of the Taiwan's researches

- Dense observation wells (single screen, multiple aquifers)
- Good quality control (maintain by the Water Resource Agency)
- Clearly hydrogeology background information
- High seismic activity
- Good quality seismic observation network (high density observation network)

Manpower

Year	2001	2002	2003	2004
Doctor	6	8	8	8
Master	8	12	12	12
Bachelor	8	6	6	6
Other	8	4	4	4
Total	30	30	30	30



Publication

Year	2001	2002	2003	2004
SCI Journal	0	1	1	3
Internal Journal	0	1	3	0
Conference Paper	1	4	7	6
Internal Conference Paper	2	5	6	5
Technical Report	2	6	3	4
Short Course	1	2	3	1
Invited Foreign Scholar	2	2	7	2

Major Accomplishments (2001~2005)

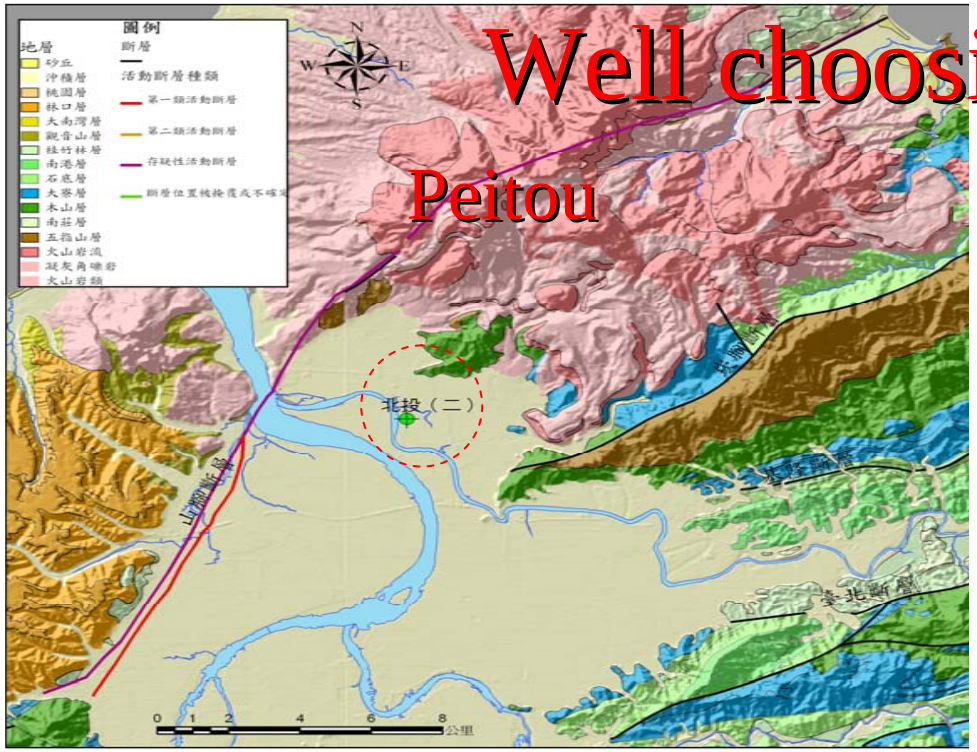
- Investigation of potential sites
- Establishment of the monitoring system
- Observation data acquisition and transfer
- Data analysis and interpretation
- Development and establish of the procedures of monitoring
- Associated Researches
  - Amplify effect of the signal from the resonate of well-aquifer system
  - Molding of a strain - pressure coupling system
  - Estimation of the rainfall effect to ground water level
  - Detecting the anomalies changes using static methods
  - Radon monitoring in the groundwater
- International cooperative research activity

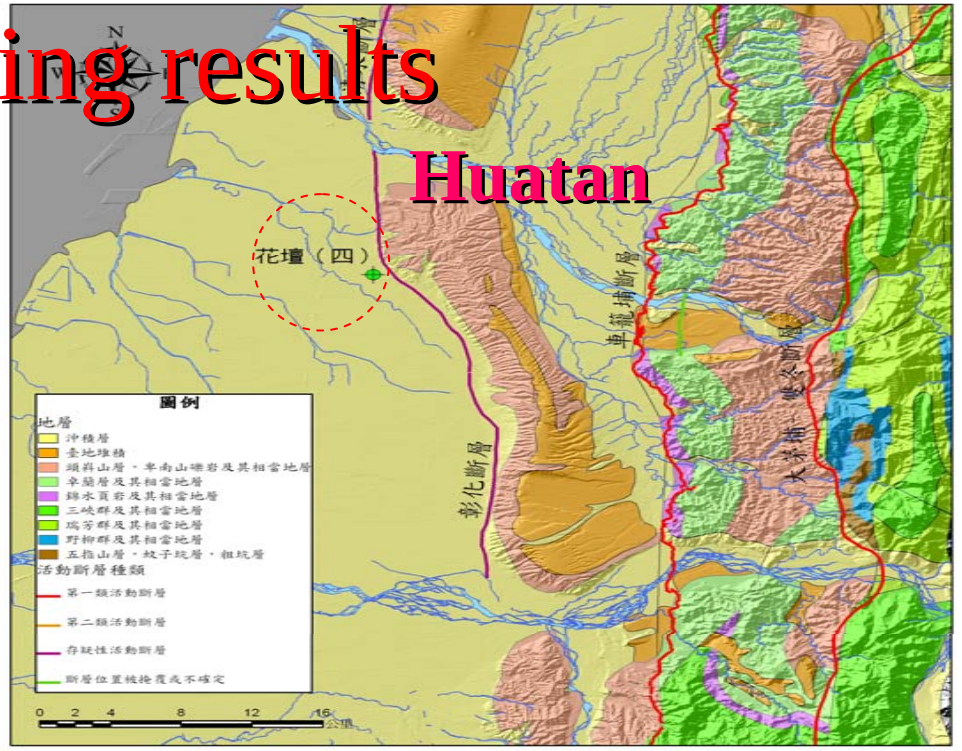
Investigation of potential sites

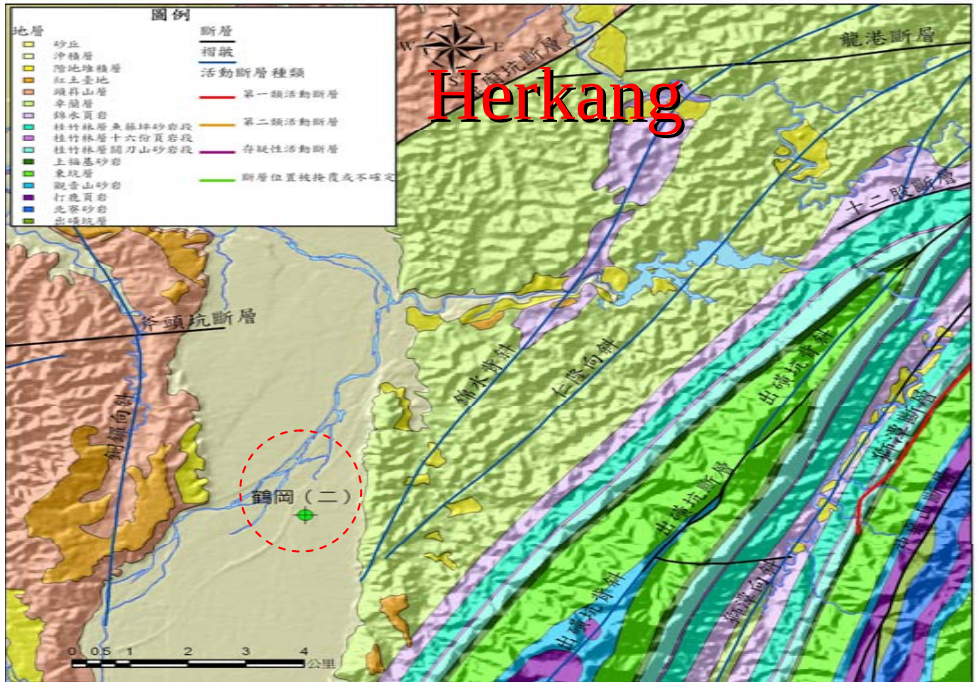
Criteria for Potential Site Selection

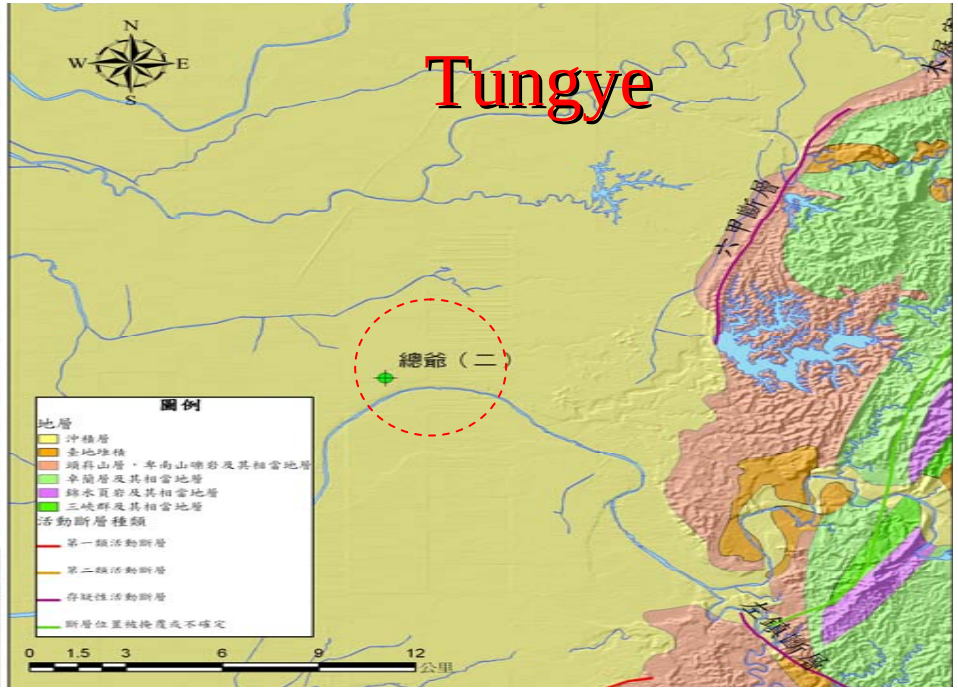
- Good Structural position
- Good confinement
- Highly strain sensitivity
- No artificial disturbance

Well choosing results

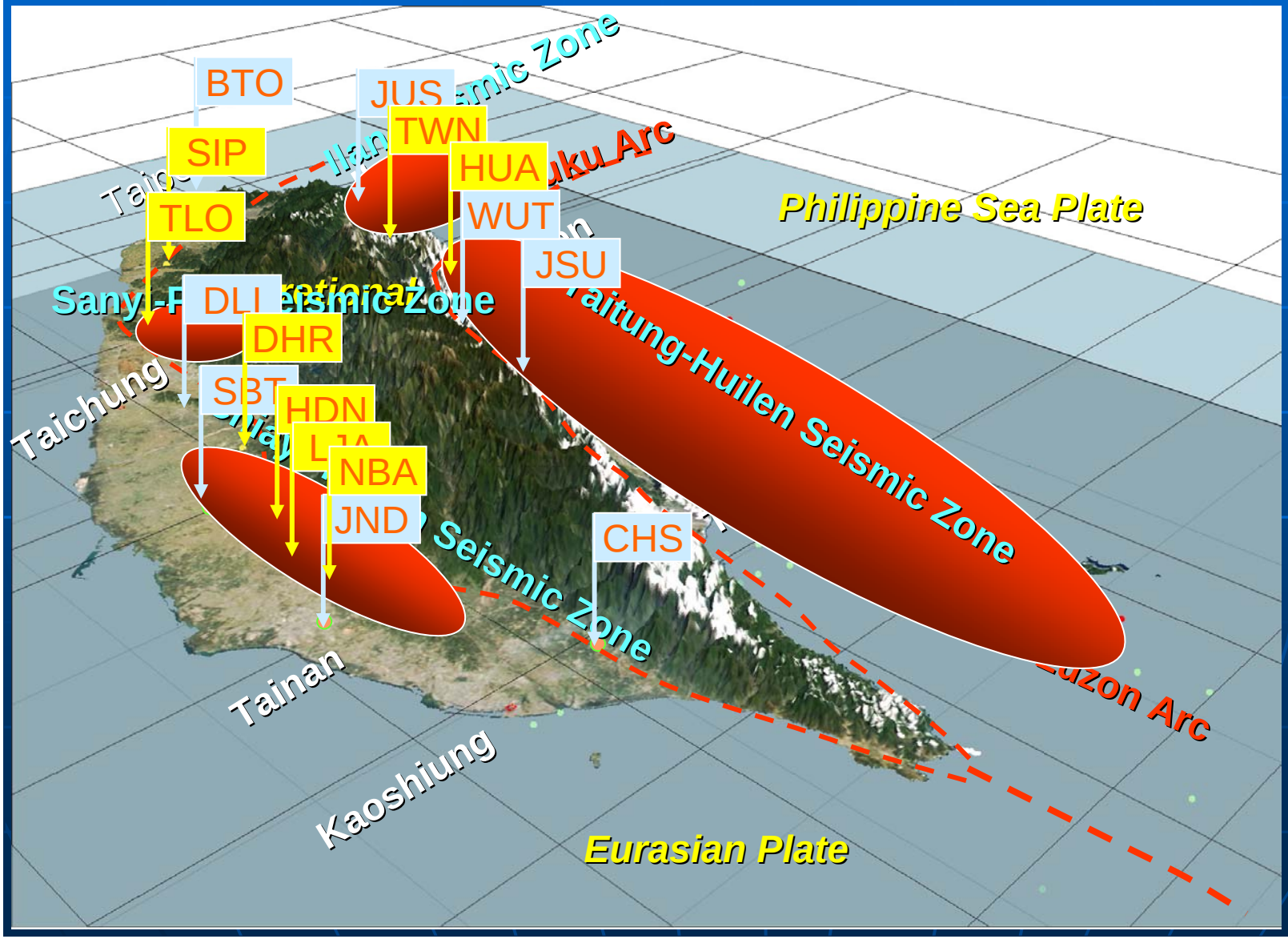








Establishment of the monitoring system: Observation Network



Well Location

XXX

Before 2004

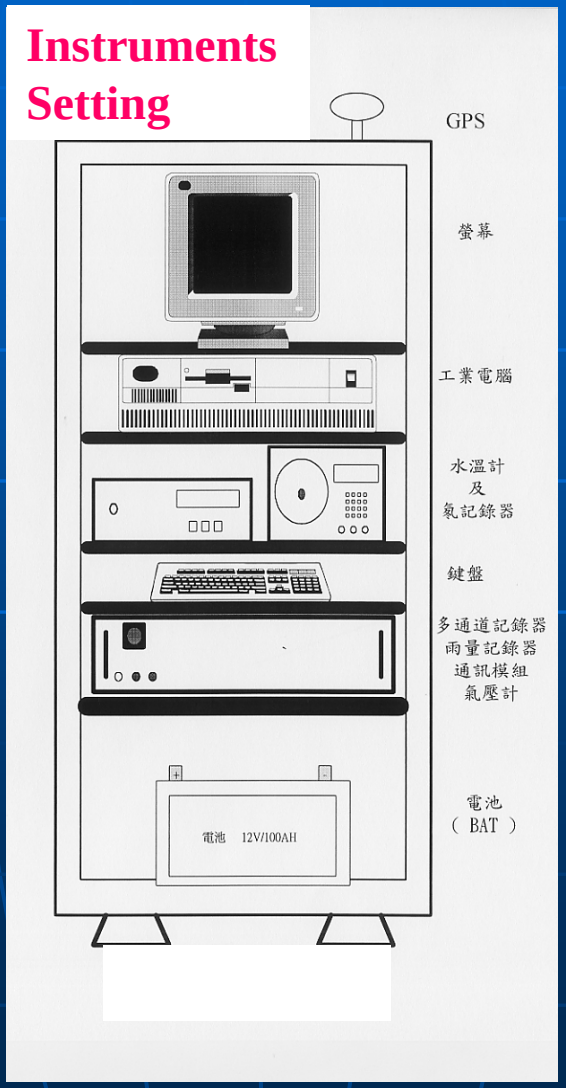
XXX

After 2004

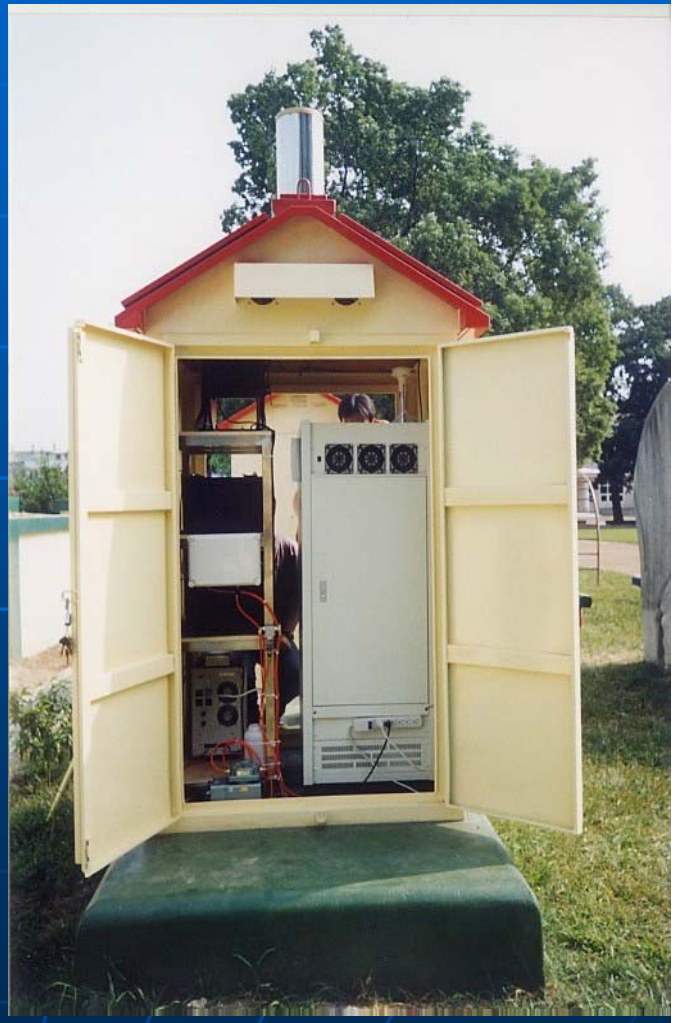
Establishment of the monitoring system

Front Side

Instruments Setting



Rear Side



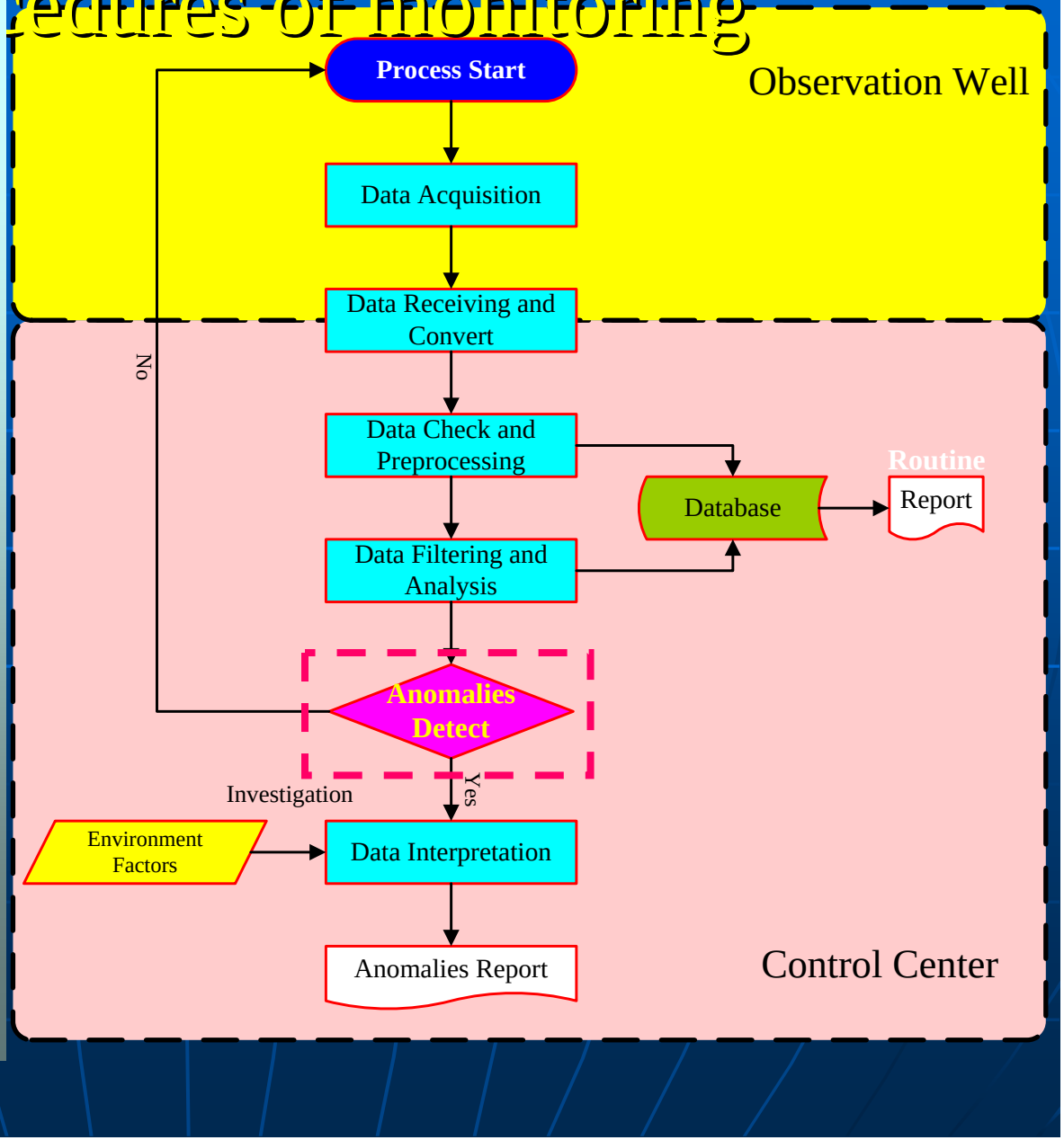
Data Receiving and Instruments Management

- Instruments Condition Check
- Data Receive
- Data Preprocess
- Data Filtering
- Anomalies Detect
- Data Interpretation
- Report Preparation

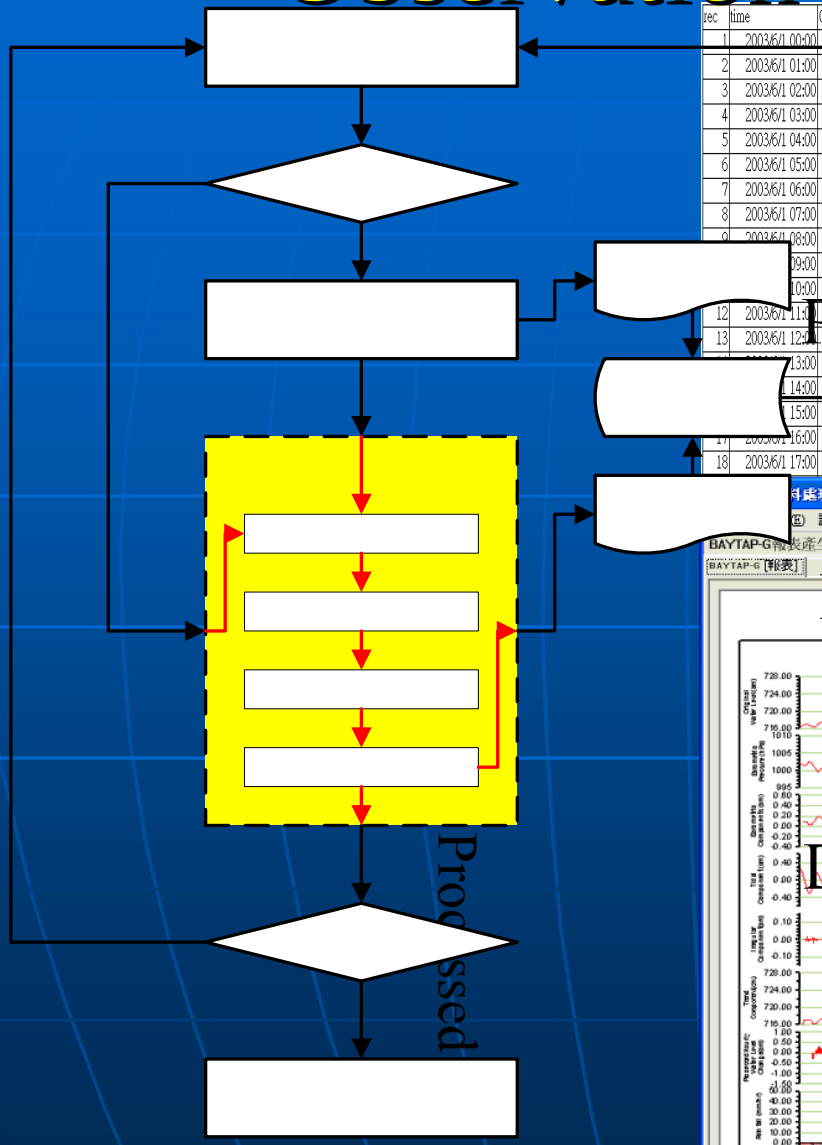
- Automation Processing

Development and establish of the procedures of monitoring

- Instruments Condition Check
- Data Receive
- Data Preprocess
- Data Filtering
- Anomalies Detect
- Data Interpretation
- Report Printing
- Automation Processing
  - More Wells
  - Highly Sampling Rate



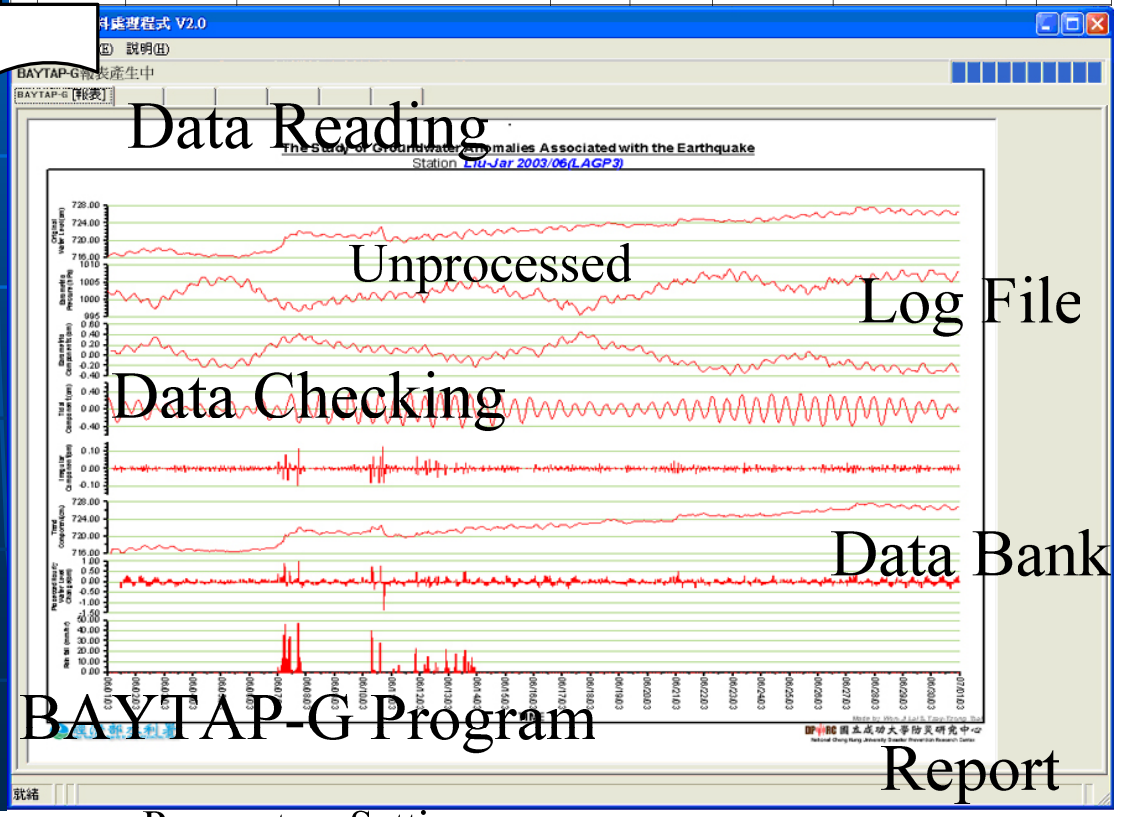
Observation Data Filtering



Processes Start

Processed

rec	time	Original Water Level	Barometic Pressure	Barometric Components(ASSOCIATED)	Earth Tide	Irregular S...al	END+IRREGULAR	Water Level Change[H(n+1)-Hn]	Rain	SMOOTH
1	2003/6/1 00:00	716.23	1002.44		0.238347337					715.7338746
2	2003/6/1 01:00	716.29	1002.06		0.255209505				0	715.9886039
3	2003/6/1 02:00	716.56	1001.6		0.216750572				0	716.2433332
4	2003/6/1 03:00	716.71	1001.43	8.33E-02	0.130308996	-1.67E-03	7.16E+02		0	716.4980625
5	2003/6/1 04:00	716.85	1001.49	8.55E-02	0.012957284	-1.29E-03	7.17E+02		0	716.7527918
6	2003/6/1 05:00	716.95	1001.45	8.70E-02	-0.112410902	-5.45E-03	7.17E+02		0	716.9808133
7	2003/6/1 06:00	717.01	1001.7	7.85E-02	-0.2214641	1.81E-02	7.17E+02		0	717.1348534
8	2003/6/1 07:00	716.82	1002.48	4.13E-02	-0.292815514	-9.00E-03	7.17E+02		0	717.0805039
9	2003/6/1 08:00	716.68	1002.53	2.18E-02	-0.312097654	-2.35E-03	7.17E+02		0	716.9726535
10	09:00	716.58	1002.33	2.86E-02	-0.27524188	4.37E-03	7.17E+02		0	716.8222372
11	10:00	716.46	1002.12	0.039239917	-0.19014942	0.008383986	716.6109095		0	716.6025255
12	2003/6/1 11:0	716.31	1002.08	0.045305648	-0.075840725	-0.016135671	716.3405351	-0.270374425	0	716.3566707
13	2003/6/1 12:0	716.39	1002.1	0.038313804	0.041401247	0.008316068	716.2702849	-0.070250129	0	716.2619689
	13:00	716.49	1000.69	0.121086221	0.134428225	-0.003059632	716.2344856	-0.035799395	0	716.2375452
	14:00	716.67	1000.14	0.156245083	0.182584429	-0.004411521	716.3311705	0.096684935	0	716.335582
	15:00	716.92	999.79	0.184776188	0.177723283	-0.001807069	716.5575005	0.226330041	0	716.5593076
17	2003/6/1 16:00	717.17	999.71	0.19735414	0.126708012	0.004571985	716.8459378	0.288437317	0	716.8413659
18	2003/6/1 17:00	717.32	1000.08	0.185743297	0.049288531	-0.000519434	717.0849682	0.239030325	0	717.0854876



Data Reading

Unprocessed

Log File

Data Checking

Data Bank

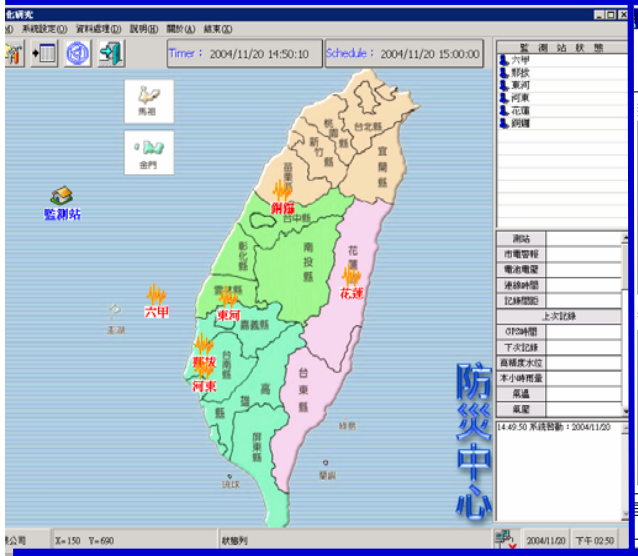
BAYTAP-G Program

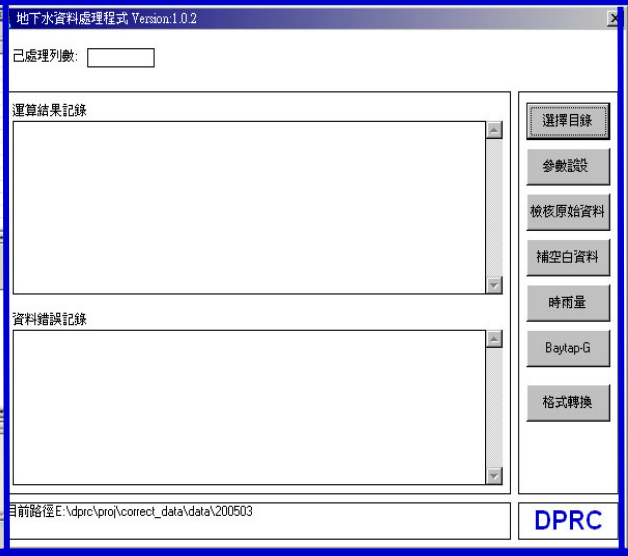
Report

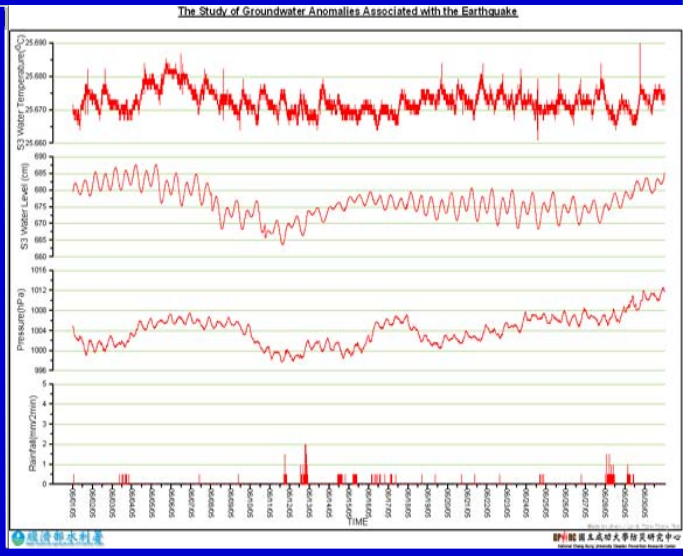
Parameters Setting

Automatic recording, analysis and anomalies detecting system

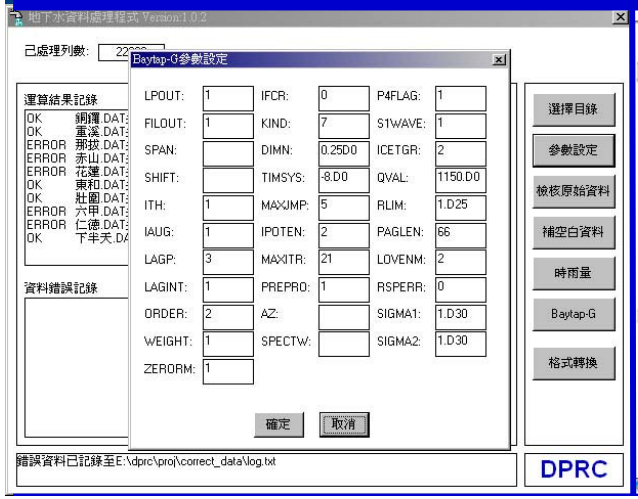
1.Recording → 2.QC, pre-processing → 3.Daily plots & reprot

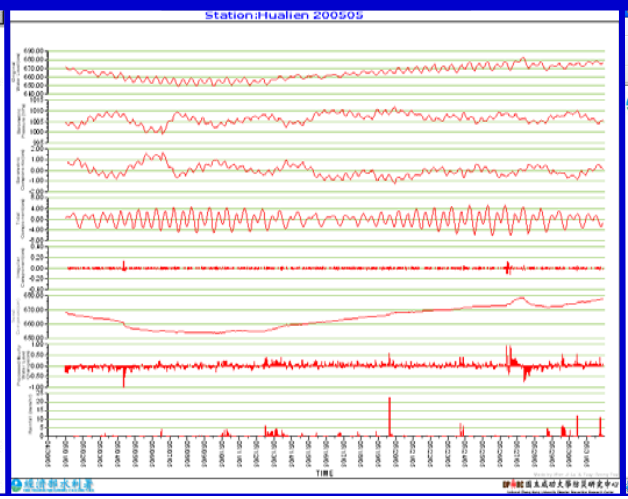


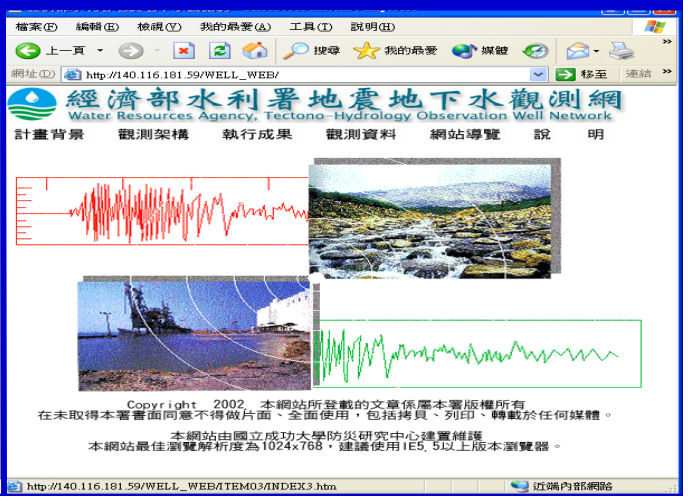




4.Data filting → 5.Anomaly Dete. → 6.Results publication

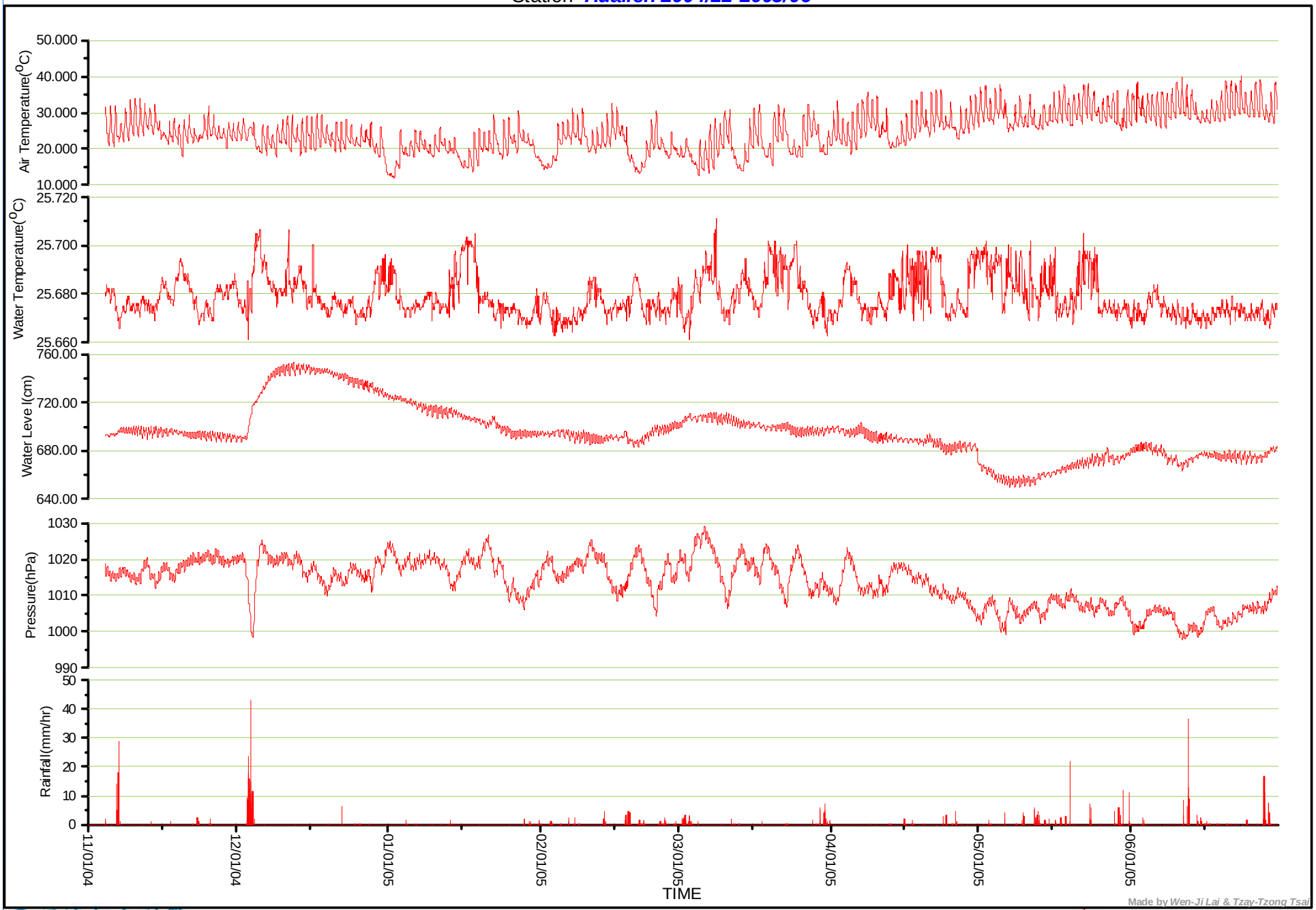






The Study of Groundwater Anomalies Associated with the Earthquake

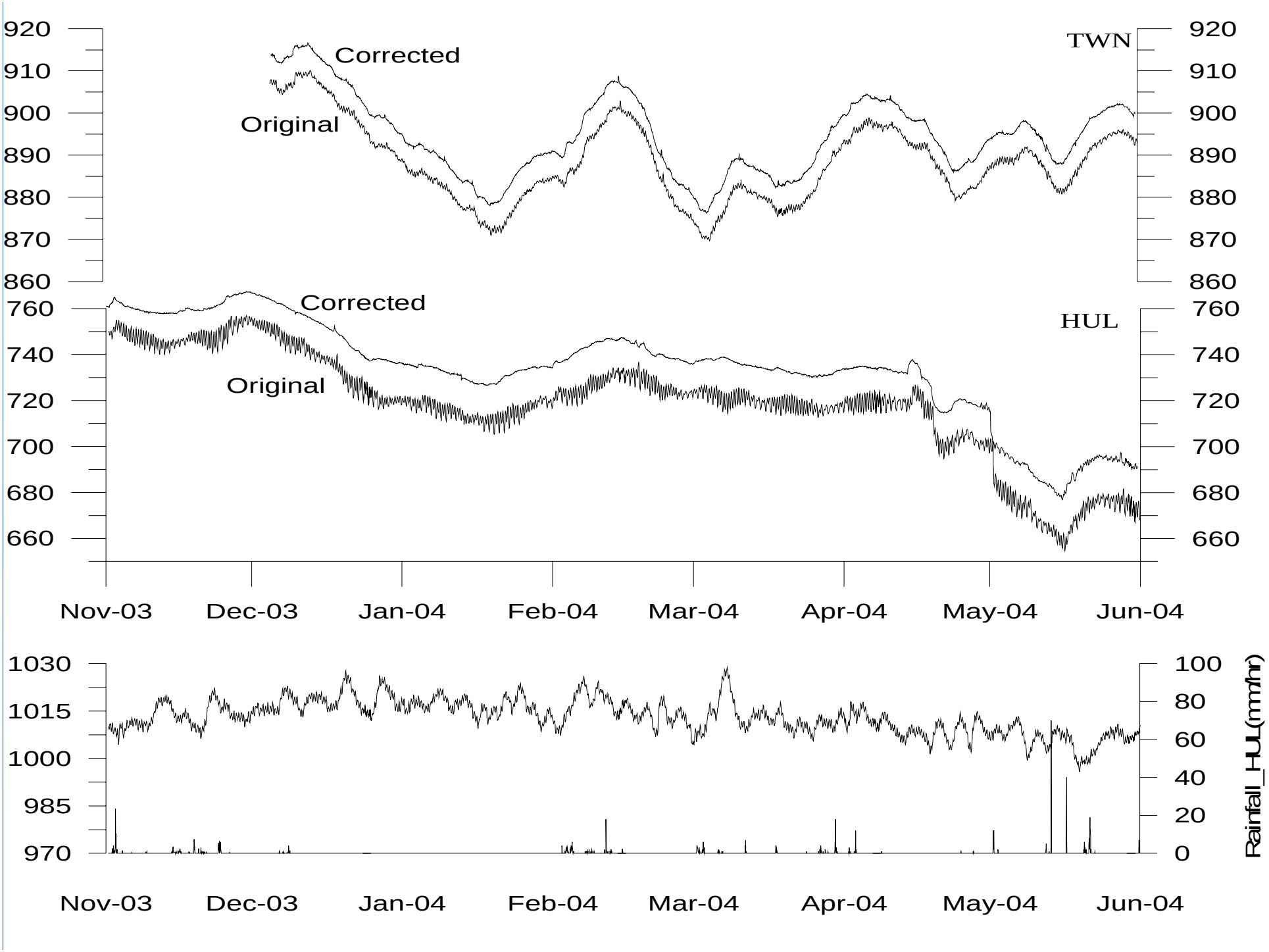
Station ***Hualien 2004/11-2005/06***



Made by *Wen-Ji Lai & Tzay-Tzong Tsai*

經濟部水利署 Water Resources Agency, Ministry of Economic Affairs

DPRC 國立成功大學防災研究中心 National Cheng Kung University Disaster Prevention Research Center


TWN
Corrected
Original
920
910
900
890
880
870
860
HUL
Corrected
Original
760
740
720
700
680
660
Nov-03
Dec-03
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
1030
1015
1000
985
970
100
80
60
40
20
0
Rainfall_HUL(mm/hr)

Evaluation of the observation wells

Obs. well	A.Noise Level (cm)	B.Str. Sen. (mm/10^{-8})	C.Events (no./yr.)	Score =(B/A)*C	Grade
HUL	0.72	5.02*	18.0	125.0	I
TWN	0.29	3.78*	9.3	121.2	I
TLO	5.14	1.14	6.0	1.3	IV
DHR	0.65	4.39	5.6	37.9	II
SBT	0.39	1.77	2.0	9.1	III
TUS	0.28	2.20	4.0	31.3	II
LUJ	0.25	1.78	4.8	33.8	II
NBA	0.34	2.92	4.4	37.8	II
JDR	0.86	2.20	2.0	5.1	III
CHS	0.78	1.58	2.0	4.0	III
SIP	4.18	2.28	2.7	1.5	IV
HRD	9.88	1.84	2.0	0.4	IV

Score =

(Str. Sen./Noise Level)

① Signal-Noise Ratio

× **Events**

②Verify potential

Grade

I :Very Good

II: Good

III: Fair

IV: Poor

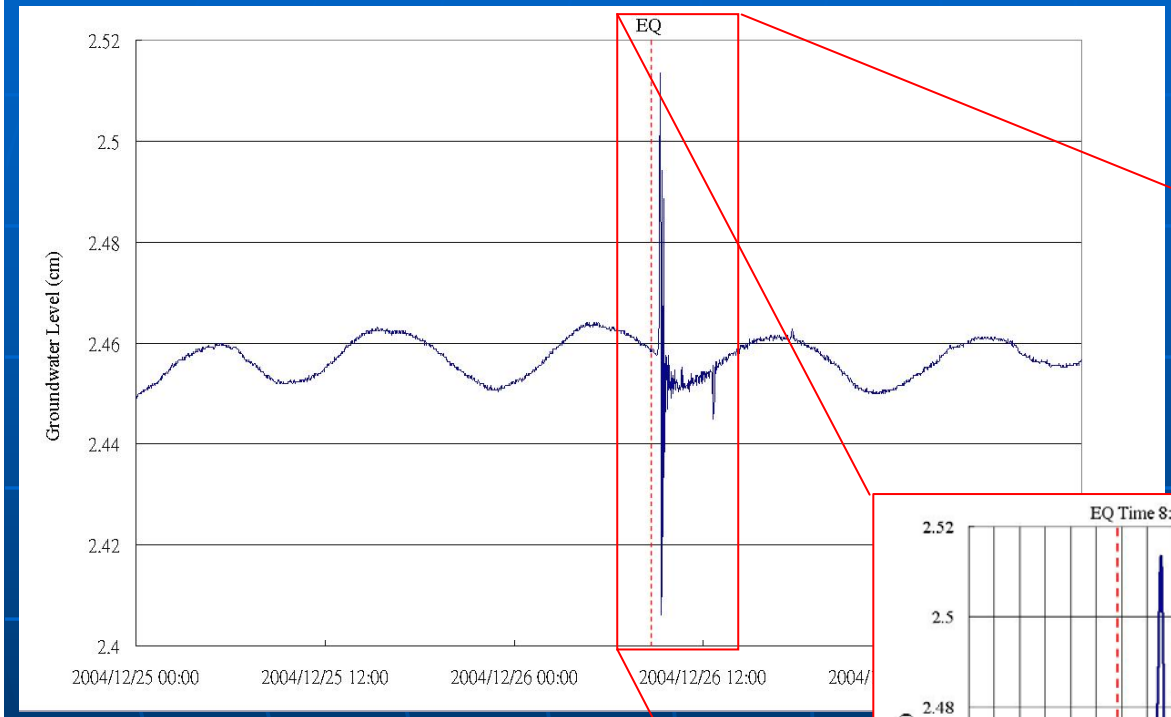
Observation Results

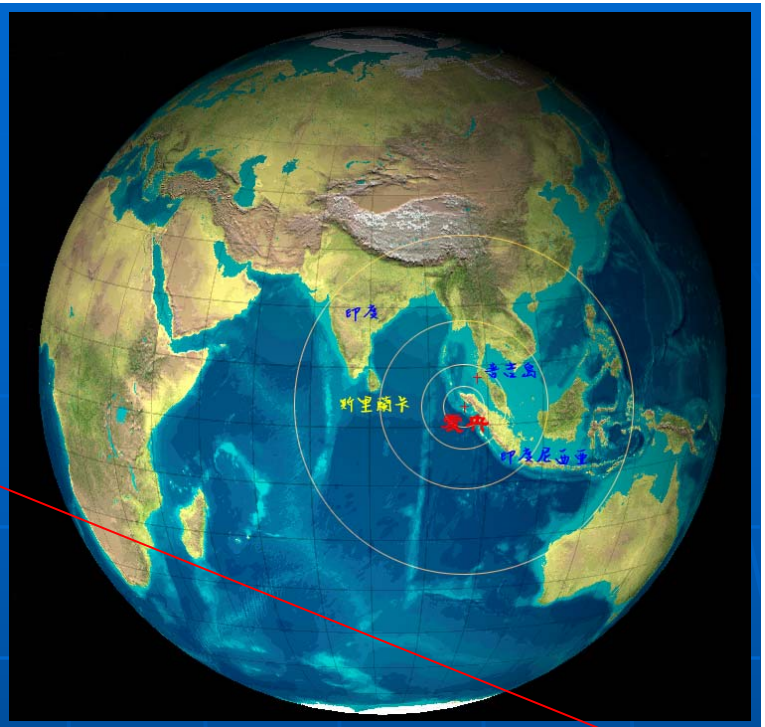
Year	2002	2003	2004	~Jun,2005	Total
No. Well	1	4	8	12	12
Events	1	9	17	14	41
Records	1	21	52	22	94

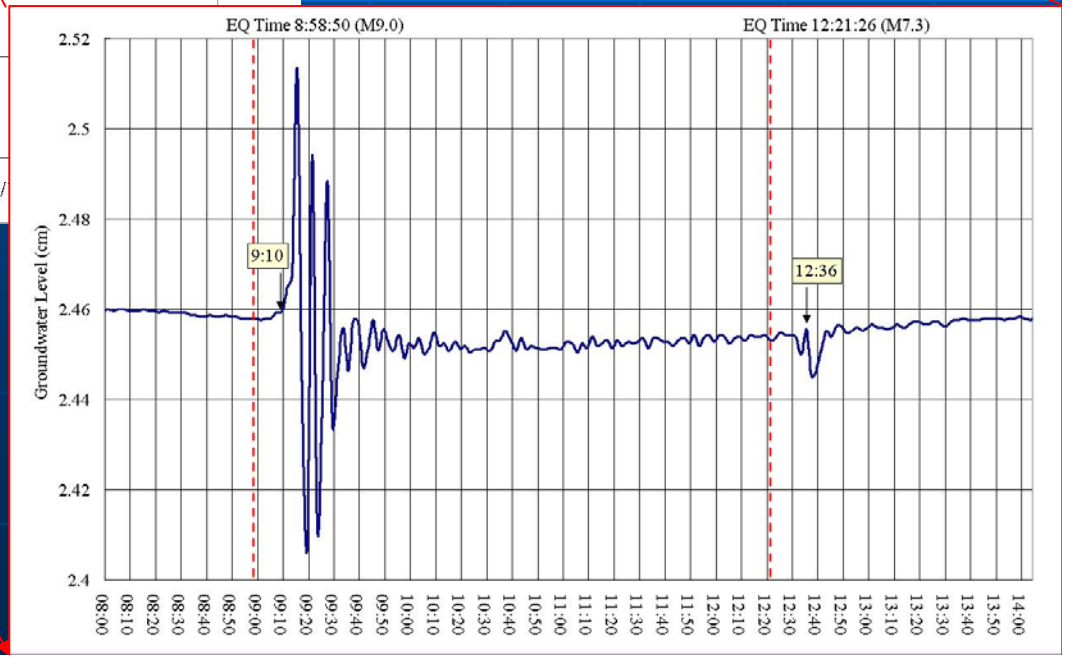
Earthquake	observation	HUL	TWN	LUJ	NBA	HDN	DHR	TLO	SIP
2003/4/3 Taina, M=4.96	2			S	S				
2003/6/10 Taitung, M=6.5	3			S	O		O+S		O
2003/6/17 Taitung, M=5.9	2				O				O
2003/12/10 Taitung, M=6.6	7	O+S	O+S	S	B	S	O+S	O+S	O
2003/12/11Taitung, M=5.7	1				S				
2003/12/18 Taitung, M=5.78	1	O							
2004/1/1Taitung, 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		

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

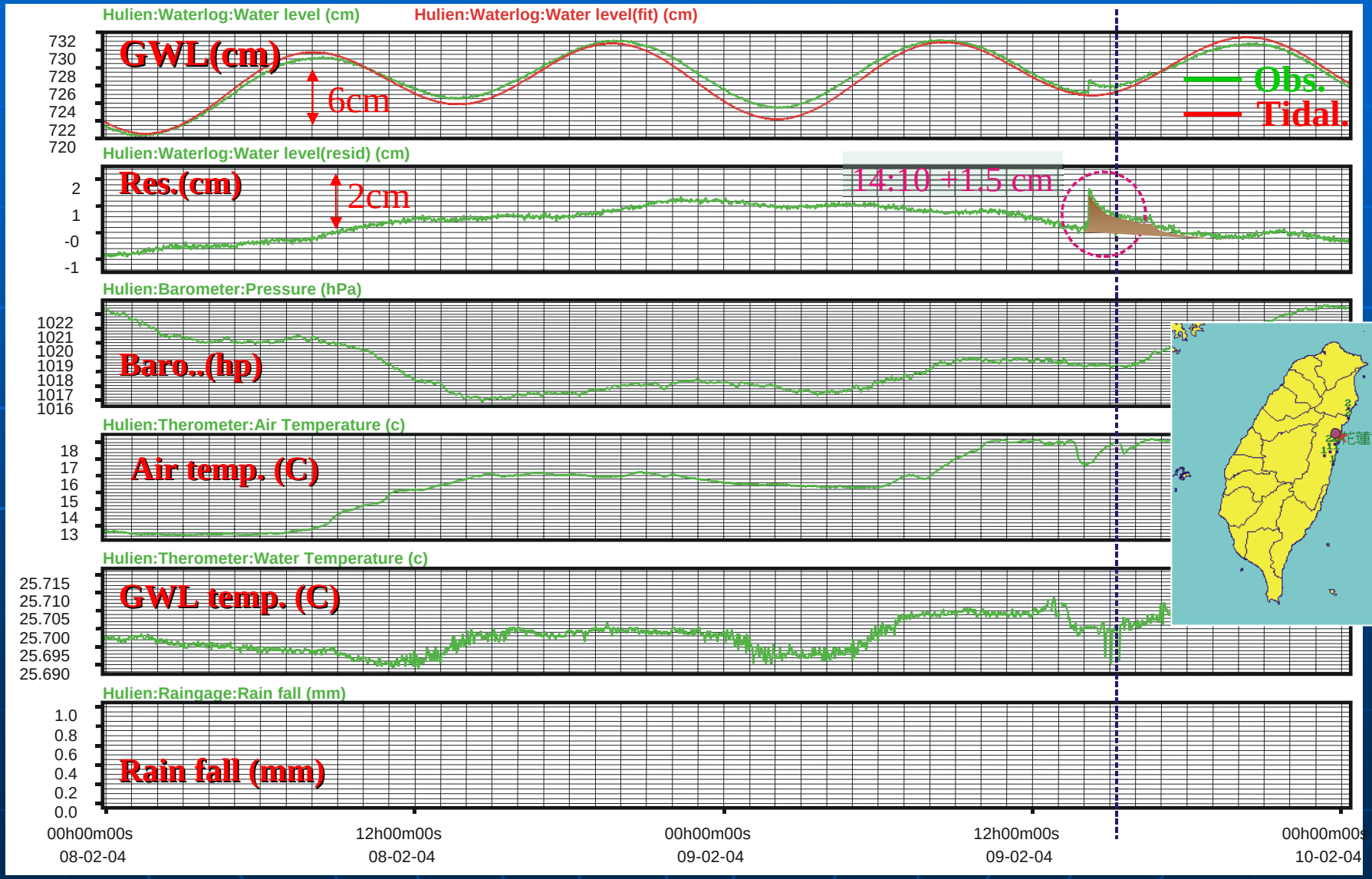
2004/12/26 Sumatra Earthquake M9.0



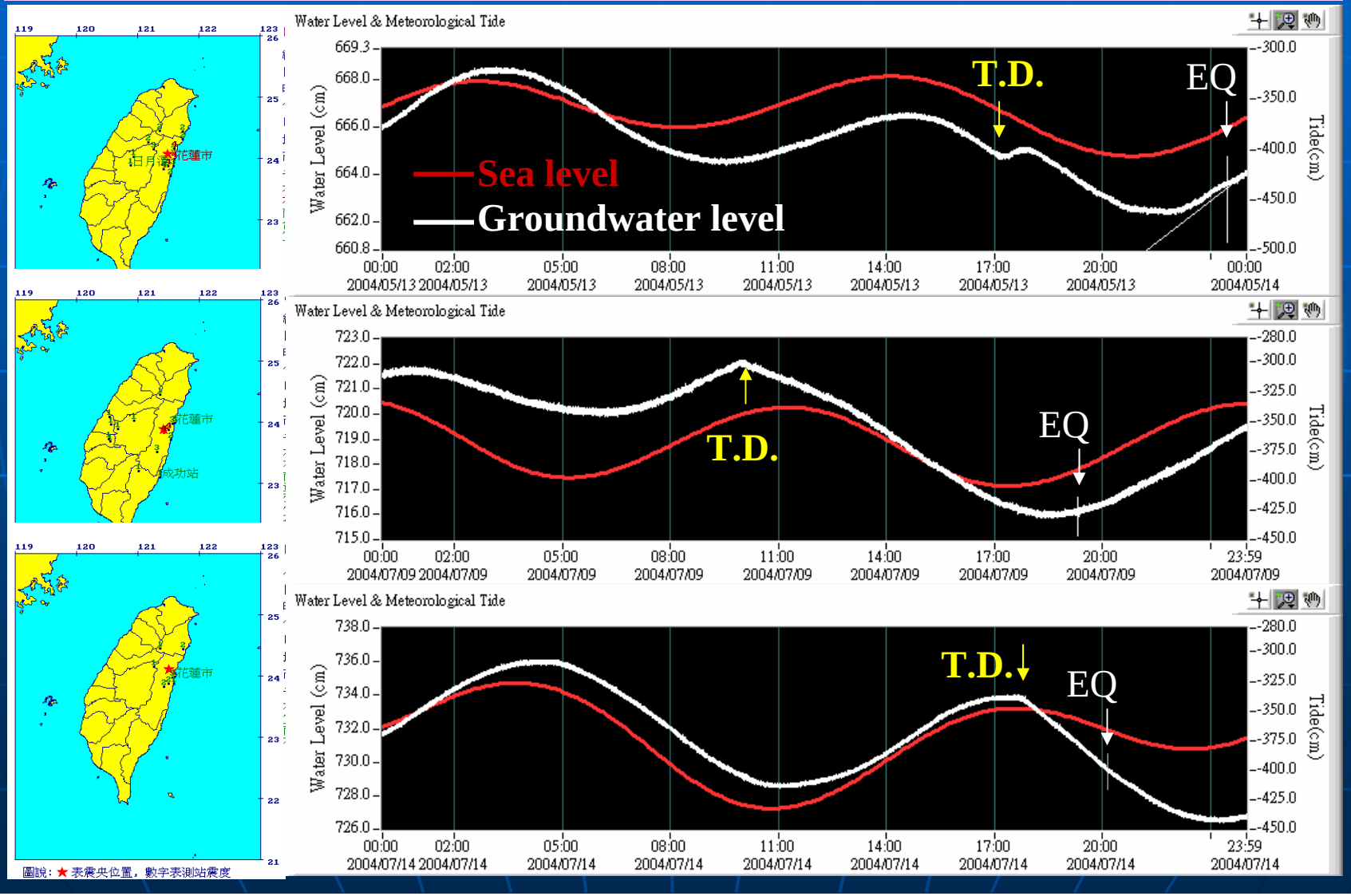




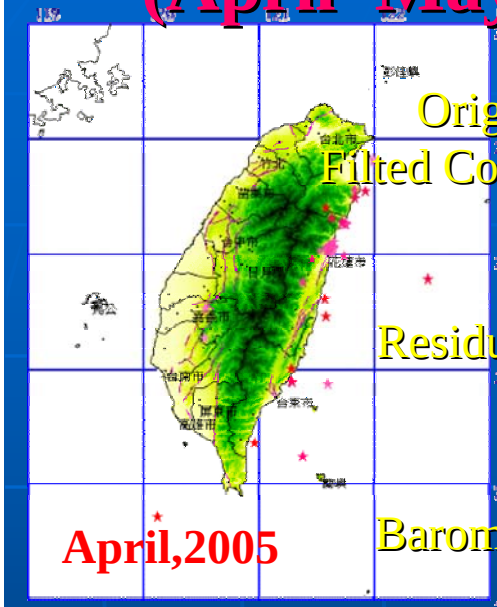
Feb. 9 15:14, 2004, Hulien Earthquake, (M=4.3 Depth 27.6 Km)

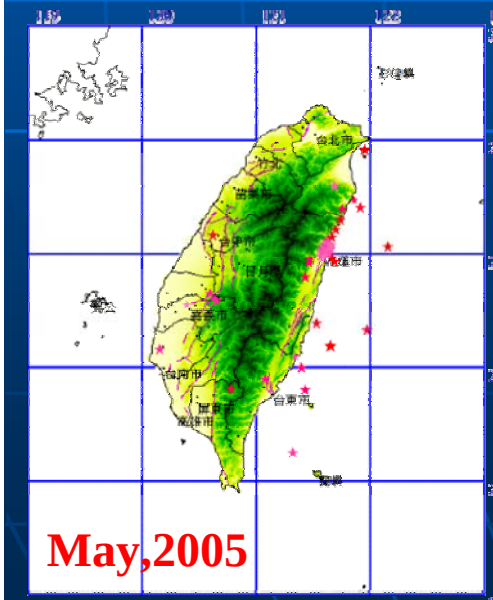


No.	Occ. Time	M_L	Lon.	Lat.	Depth (km)	Distance (km)	Obs. Sta.	Intens.
93053	2004/05/13 23:28:47	4.6	121.51	24.05	18.9	13.3	HUL	4
93069	2004/07/09 19:19:29	4.8	121.43	23.86	19.5	23.3	HUL	3
-	2004/07/14 20:04:30	4.1	121.52	24.09	21.1	15.7	HUL	1



Seismic activity and the groundwater level changes (April~May, 2005)





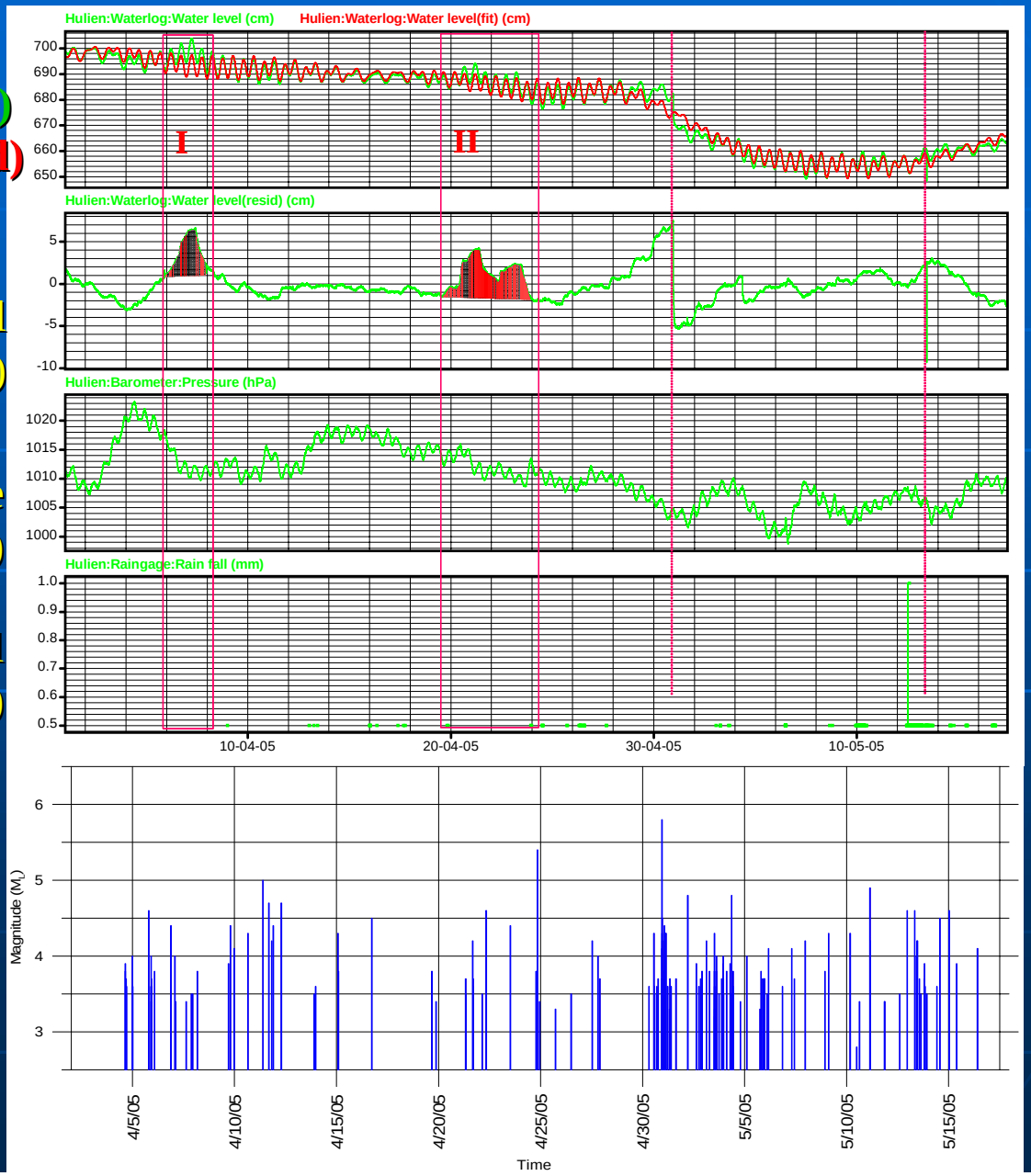
Orig. WL. (green)
Filted Components(red)

Residual water level (cm)

Barometric Pressure (hpa)

Rainfall (mm)

Seismicity (M_L)



Other Approaches on the Groundwater Anomalies Associated with Earthquake

- Preparation for Long-Term Monitoring
- Planning for the Standard Procedures for detecting the Anomalies
- Research for theoretical support of observation results

- Anomalies detection techniques
- Early warning system for foundation engineering
- Application for water resources mangement

International cooperative research activity

"Hydrological and geochemical research for earthquake Prediction in Taiwan (February 2002 - March 2005)"

- Exchange of information and personnel
- Annual workshop
- Publication
- Planning for extended cooperation

5. Prospects in the future cooperation

Both Taiwan and Japan are situated in the boundary zone between the Eurasian and Philippine Sea plates and often attacked by large earthquakes. DPRC-NCKU has now abundant data produced by the dense groundwater observation network. IGG-GSJ has 30-year experience of the hydrological and geochemical research for earthquake prediction. Therefore continuous cooperative research of DPRC-NCKU and IGG-GSJ will give much contribution to hydrological and geochemical research for earthquake prediction. Therefore DPRC-NCKU and IGG-GSJ have decided to continue this cooperative research for next 5 years. We are sure that the cooperative research will make much contribution to reducing earthquake hazards in Taiwan and Japan in future.

6.Publications

6-1 In English

Chang, W.Y. (2002) The program of earthquakes and active-fault research (PEAR) in Taiwan, Geological Survey of Japan Open-File Report, 384.

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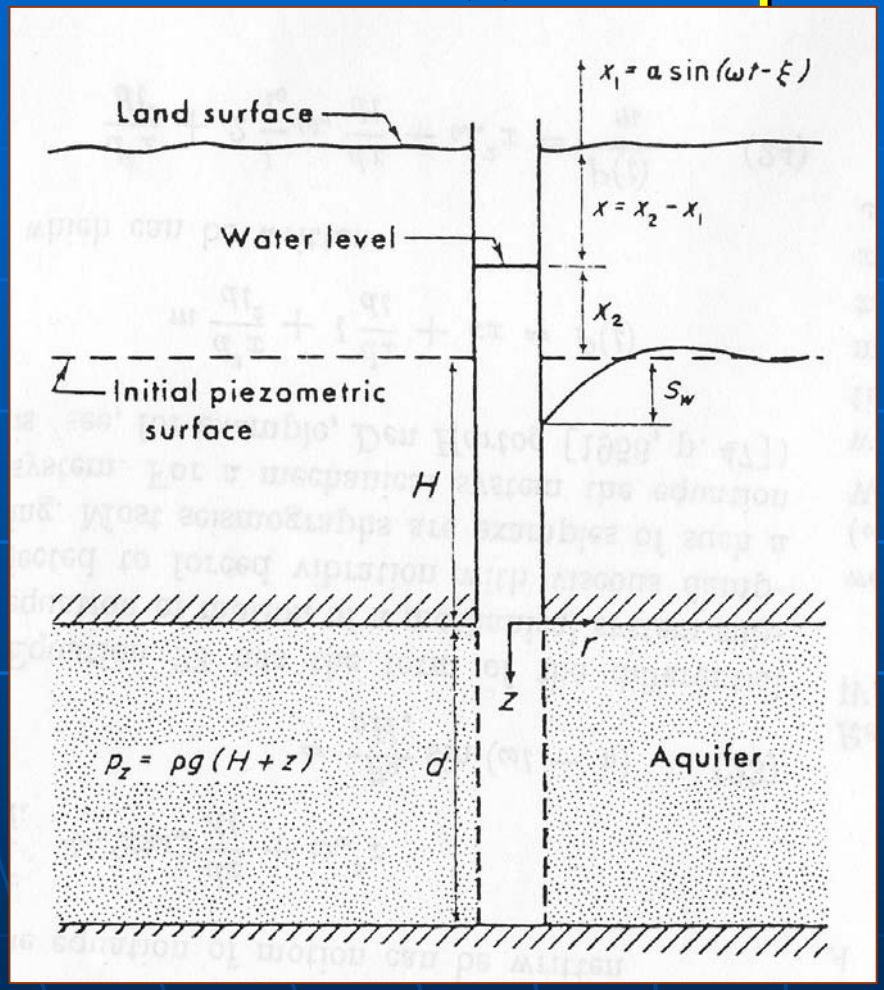
Future Plans

Stage 1: Construction of the Well-Aquifer System



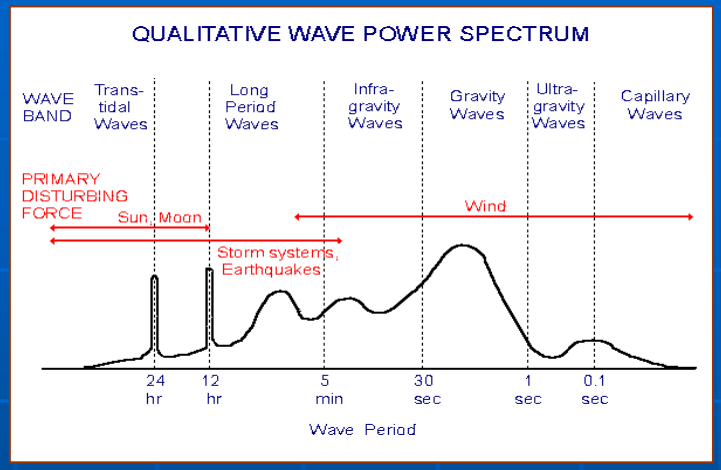
Well-Aquifer System (Cooper et al.,1965)

- The components of well-aquifer system
  - **Mass** (Water in well and parts of the water in aquifer)
  - **Restoring Force** (the difference between well and aquifer)
  - **Damping Force** (the friction along the well body and flow through the well and aquifer)
  - **Surface Tension Force** of the water in well

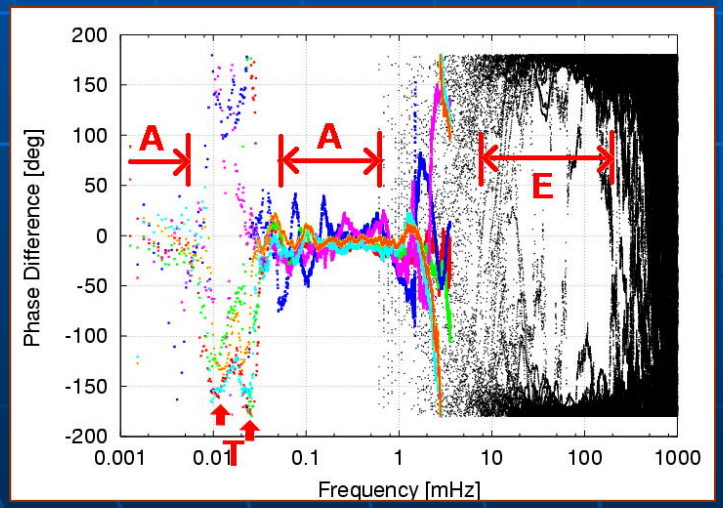
- The limitation of the observation made by Well Radius、Properties of Aquifer (Conductivity、Storativity)

- The amplify or attenuation factors for pressure between the well and aquifer

Stage 2：Extracting the Differential Components of the Water Level fluctuations



The spectrum of different sources (long period)

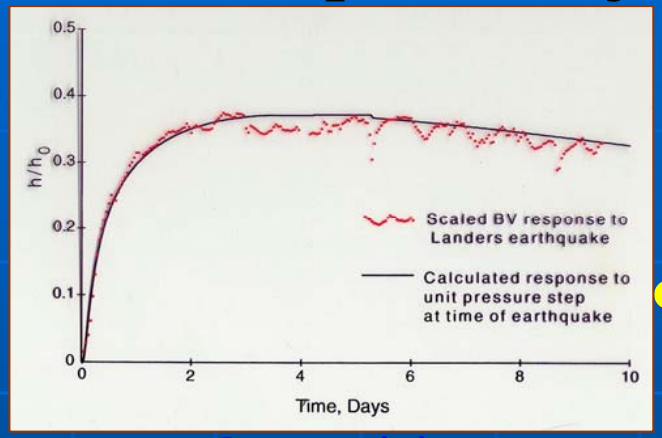


The spectrum of different sources (short period)

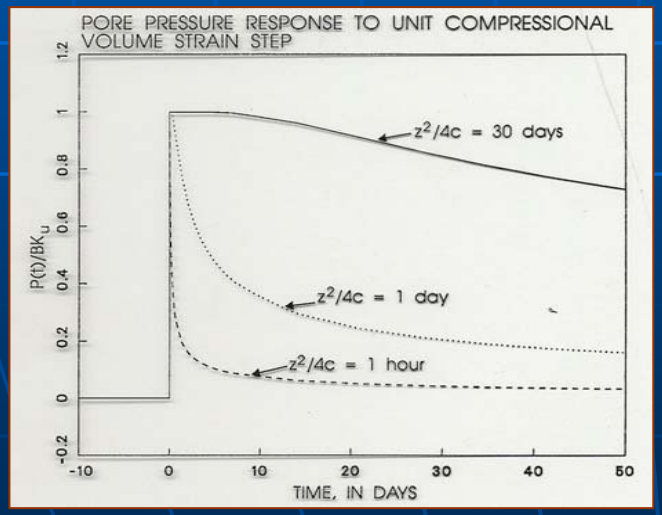
(Ishimura, 2002)

- Extract the different components of the water level fluctuations to estimate the response of the well-aquifer system to different sources.
- Using the characteristic responses to estimate the material parameters of well-aquifer system .
- Setup the system parameters and boundary condition prepare for testing the assumption.

Stage 3：Derived the Poroelastic Properties of the Well-Aquifer System by Stochastic Methods



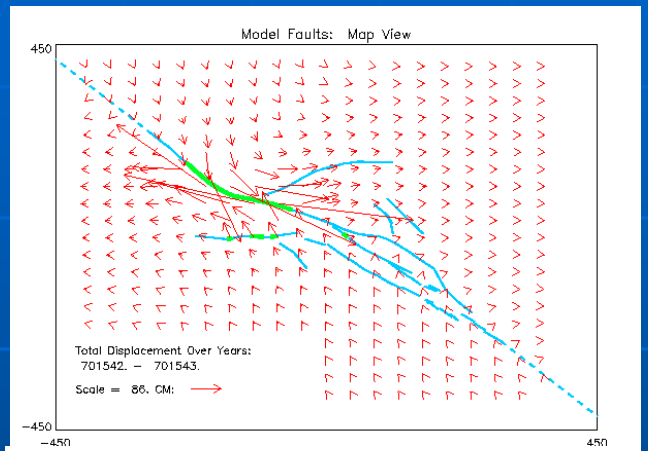
Curve Fitting



Type Curve Plotting
(Roeloffs, 1996)

- Using the stochastic and statistical methods to estimate the poroelastic parameters of the well-aquifer system

Stage 4： Construction of the Faulting and Water Pressure Coupling Processes



Faulting and stress field distribution (USGS , 2002)

- Precursory changes got no spatial relation with source region of earthquake.
- Difference between sensitive and non- sensitive wells
- Material properties of aquifer
- Characteristic of signal propagation
- Characteristic of faulting processes

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- **Resonance of Well-Aquifer system**


Thank You!