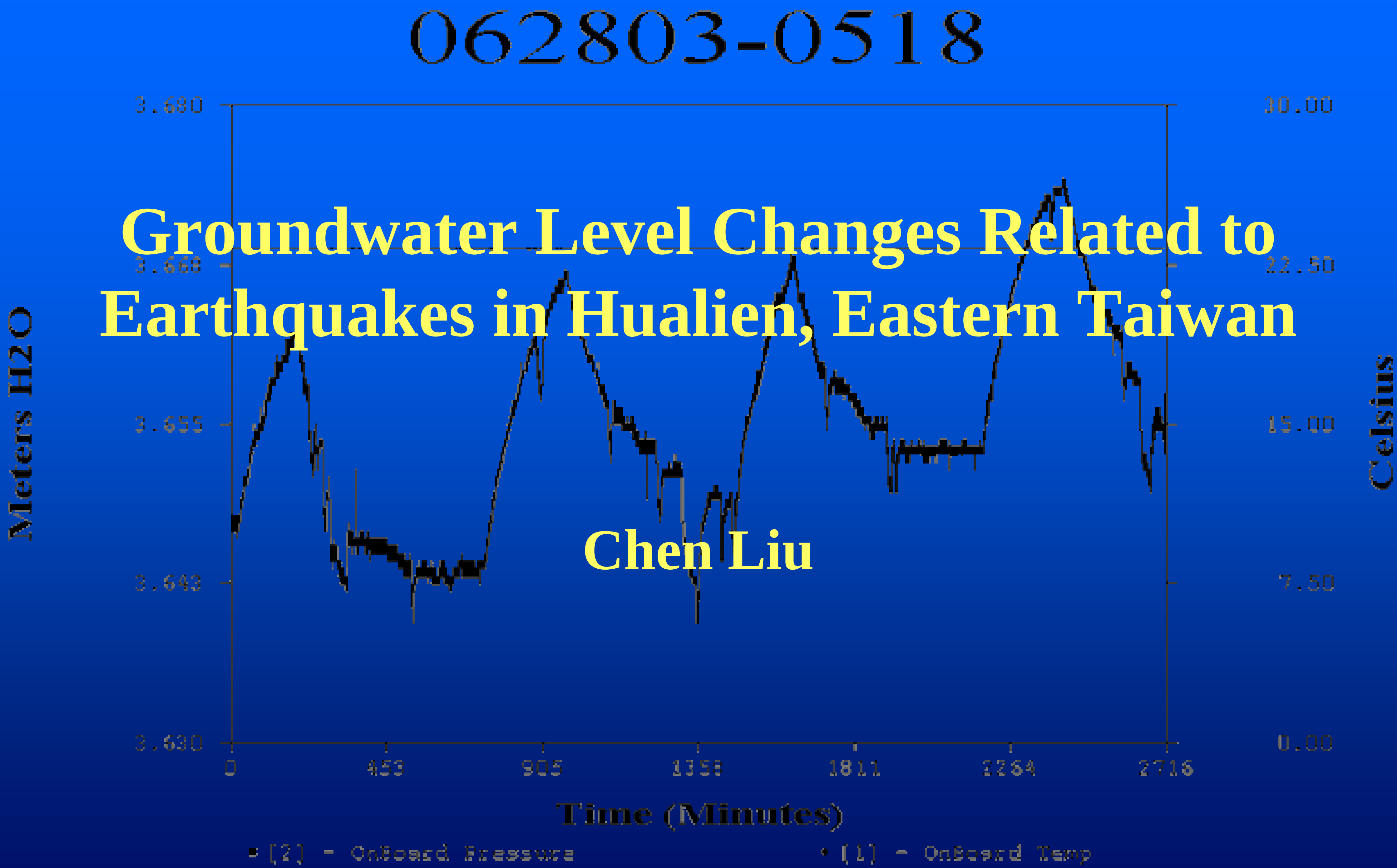
Groundwater Level Changes Related to Earthquakes in Hualien, Eastern Taiwan

Chen Liu



Introduction

- Past Examples of Groundwater Level Changes Related to Earthquakes:
    - In Japan
    - In Taiwan
- Motivation for Present Research :
    - Scientific Considerations
    - Personal Considerations
- Seismicity of the Research Area
- Water Level Recording System
- Recorded Data from Two Different Wells
- Preliminary Results

Examples of Earthquake Related Groundwater Research in Japan (Wakita, 1982)

No.	Date	Earthquakes: Epicentral location(s) (names)	M	H	Accompanying phenomena: Groundwater: Flow rate: Increase	Decrease	Temp.: Rise	Fall	Quality	Clouding	Gas release	Spouting sand, water	Others	Remarks
109	Sep. 9, 1969	Central Gifu Pref.	6.6		○					○		○		Wara Village (Gifu): Immediately after the earthquake, the well water became muddy, then 2 to 3 hours later it became cloudy. Groundwater increased and became brown and sandy.
110	Jun. 17, 1973	Nemuro Peninsula offshore	7.4											
111	May. 9, 1974	Izu Peninsula, Shizuoka Pref. (Izu Peninsula offshore earthquake)	6.9		○		○		○					Coseismic water level changes were recorded at water level observation wells in the Kanto and Tokai districts. A correlation was found between the distribution of the wells that showed a water level change and the earthquake source mechanism. At hot springs south of Kamo Village and Kawazu (Izu Peninsula), an increase in the amount and temperature of spring water were generally noted. The spring water became cloudy during a two week period at Daisenzan, Hatage Hot Springs (Izu Peninsula).

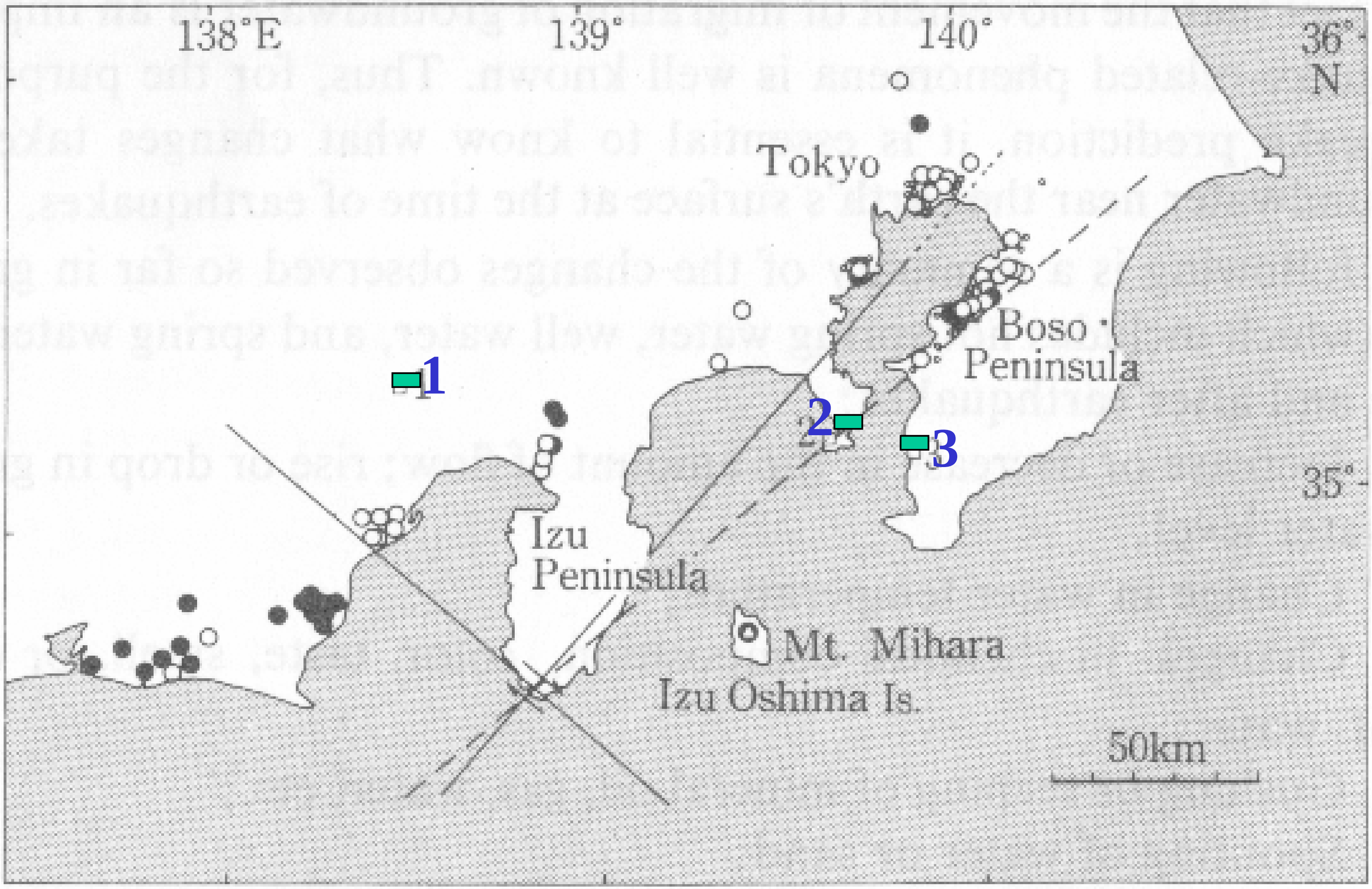


Fig. 8.1 Coseismic water level change at the time of the Izu Peninsula offshore earthquake on May 9, 1974 [Wakita, 1975].

1, 2, and 3 indicate crustal movement observatories at Fujigawa, Aburatsubo and Nokogiriyama, respectively.

Example of Groundwater Level Changes due to Earthquakes in Taiwan (Chia et al., 2001)

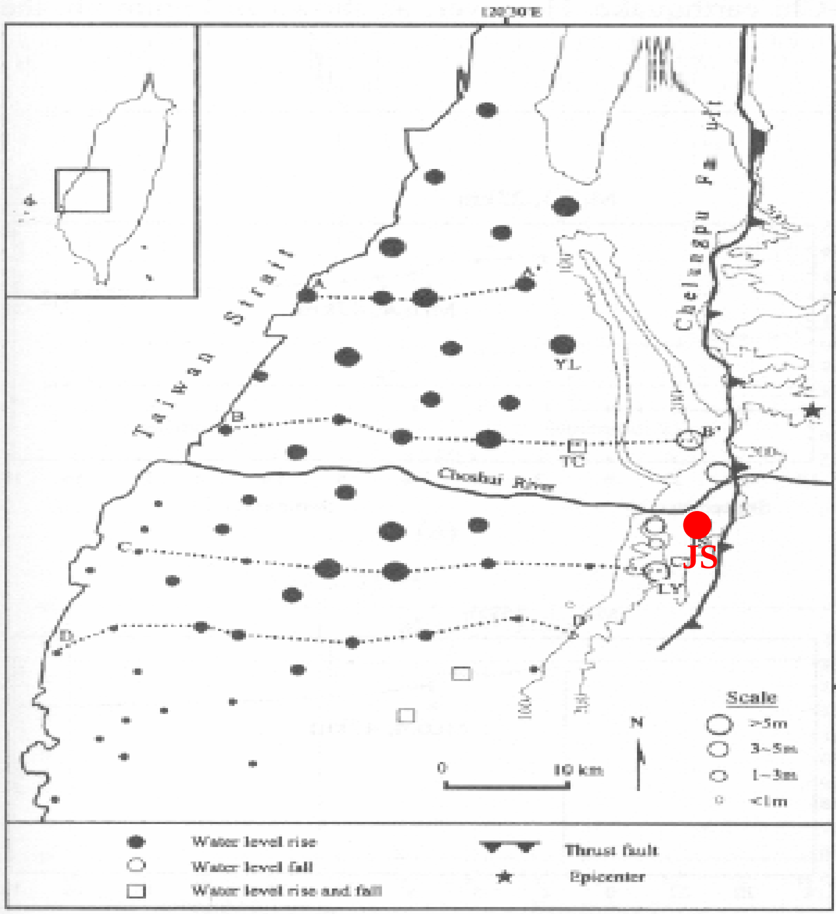


Figure 1. Location of Choshui River alluvial fan and distribution of 157 monitoring wells clustered at 64 stations where coseismic changes of groundwater level were observed at the time of Chi-Chi earthquake. Open circles indicate stations where the groundwater level fell, solid circles indicate stations

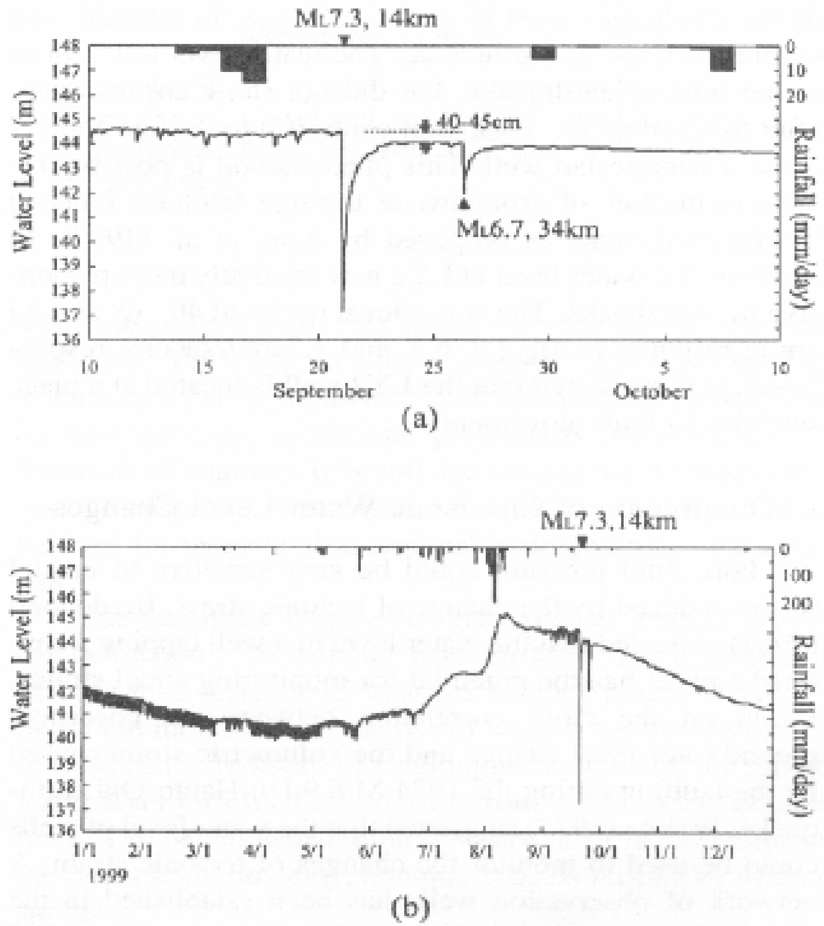
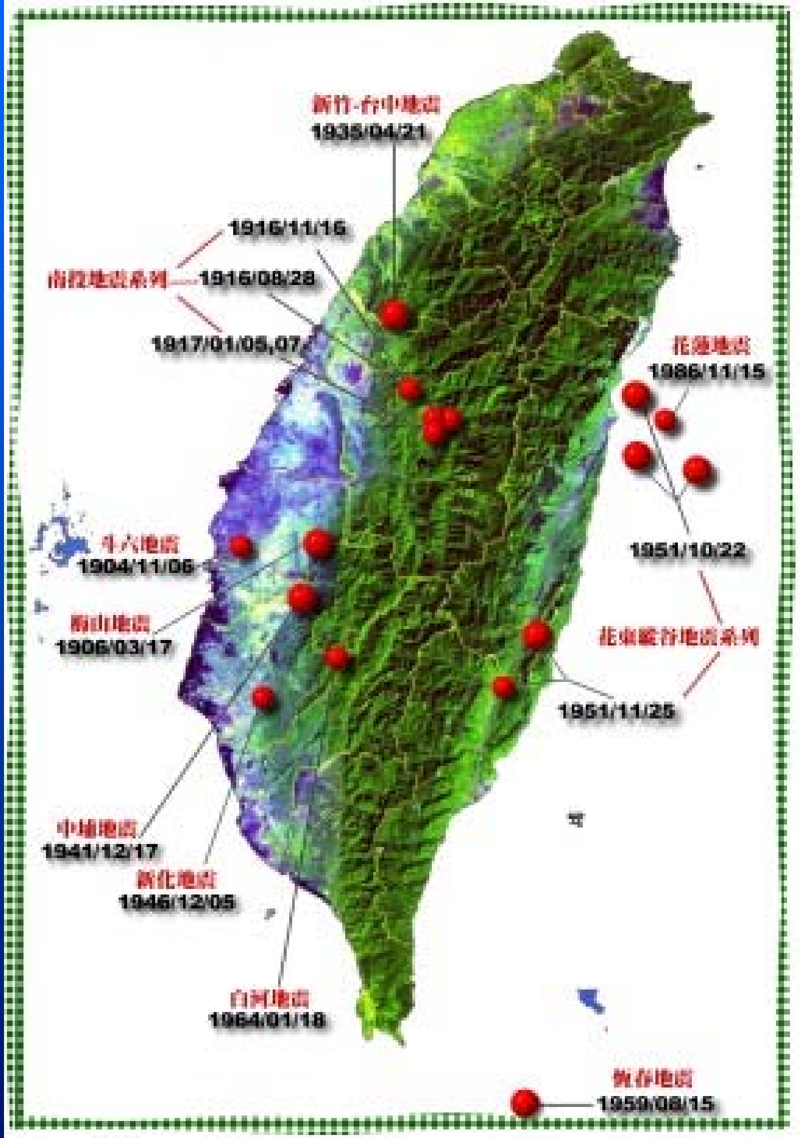


Figure 6. Variation of hourly water level and daily rainfall at the JS1 well. (a) Records from 10 September to 10 October 1999. (b) Records from 1 January to 31 December 1999. The JS1 well, screened at the depth from 66 to 96 m, was installed to monitor the water level of a partially confined gravel aquifer. The water level rose during the rain season from May to September and declined during the dry season from October to April. Local pumping was active from January to June and in September.

Seismicity in the Research Area



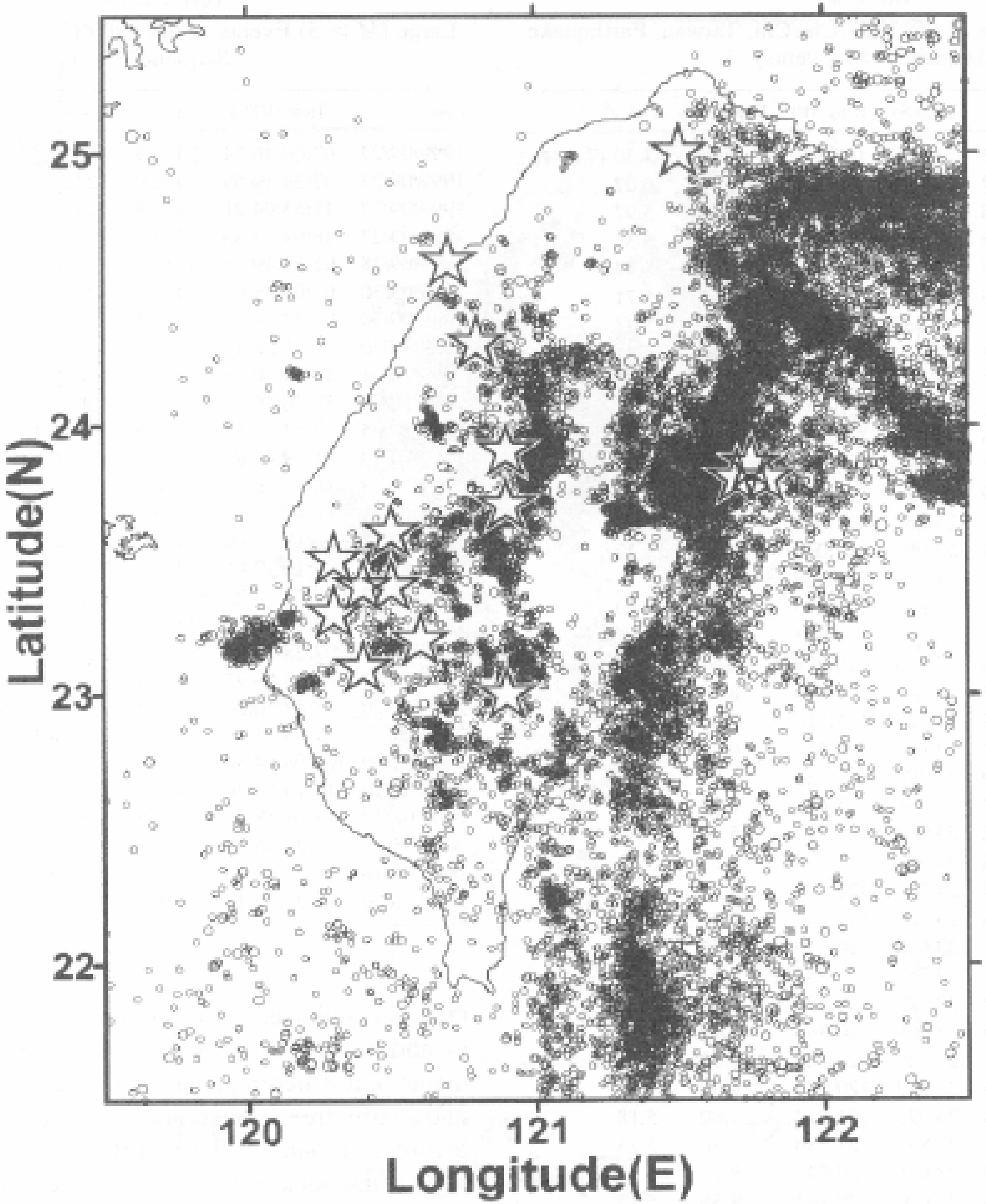
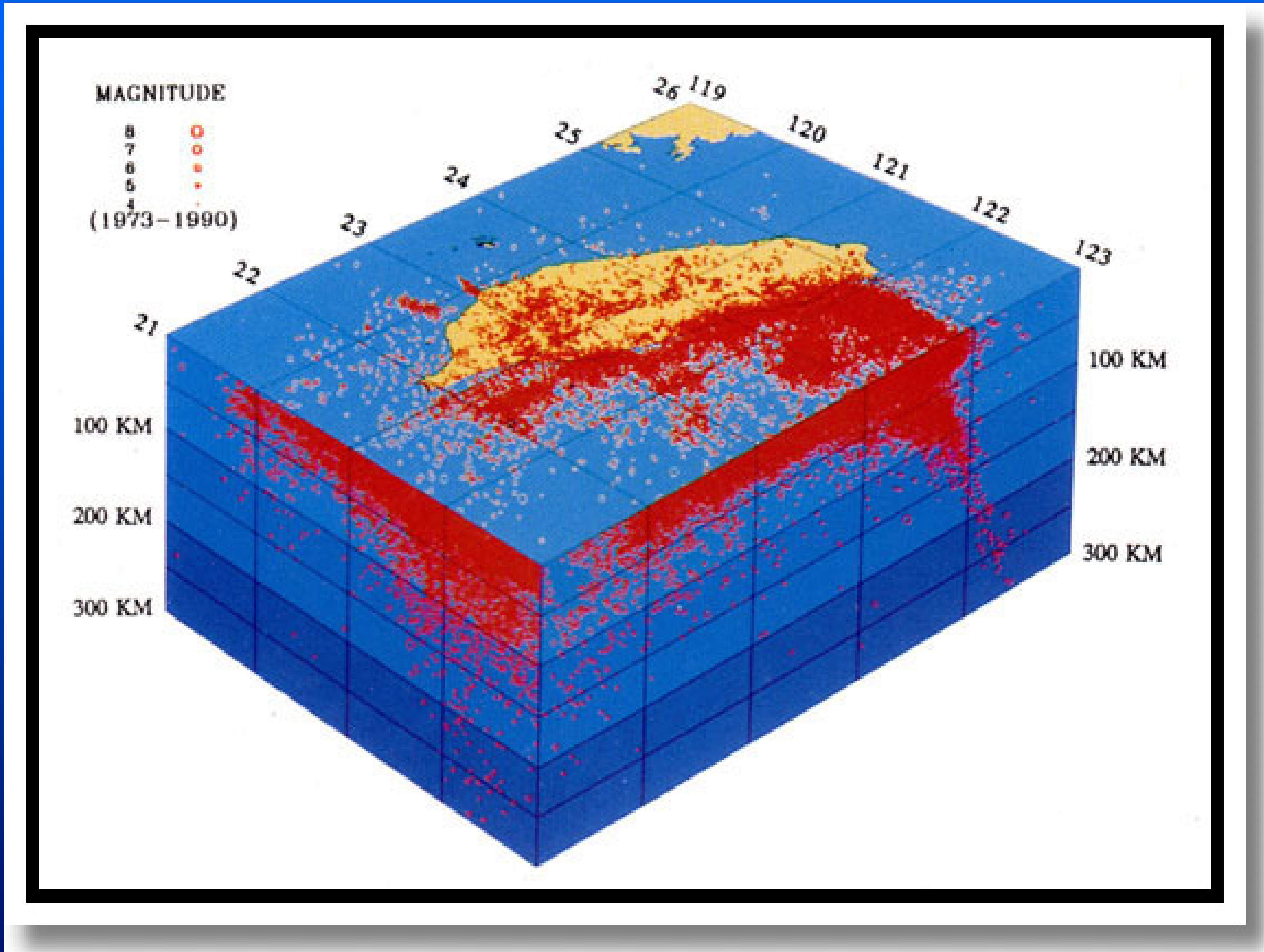
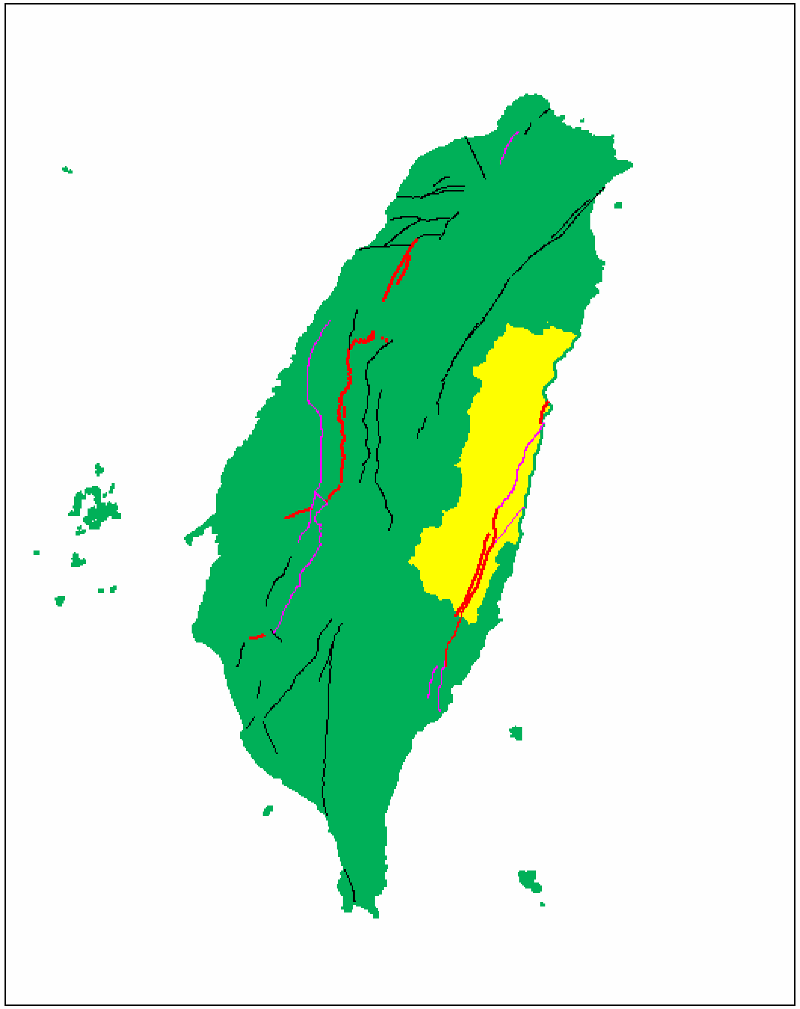


Figure 4. Seismicity of Taiwan from 1990 to 1999 for events of $M_L > 3$. Also shown are the 17 damaging earthquake in Taiwan during the twentieth century (in open stars).

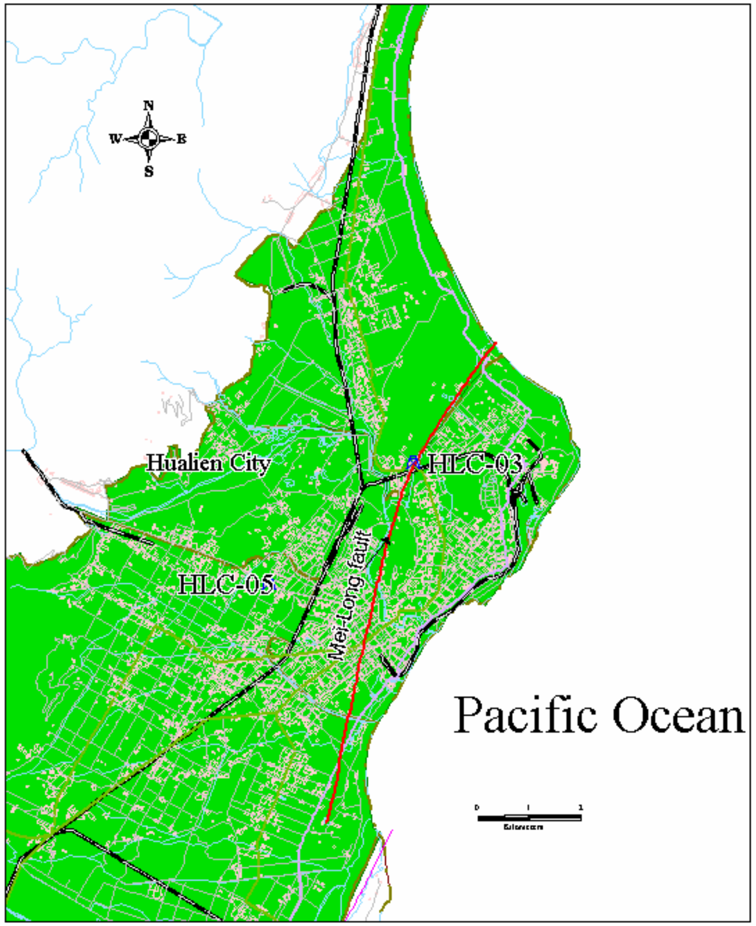
The Structure of Taiwan



Distribution of Active Faule in Taiwan

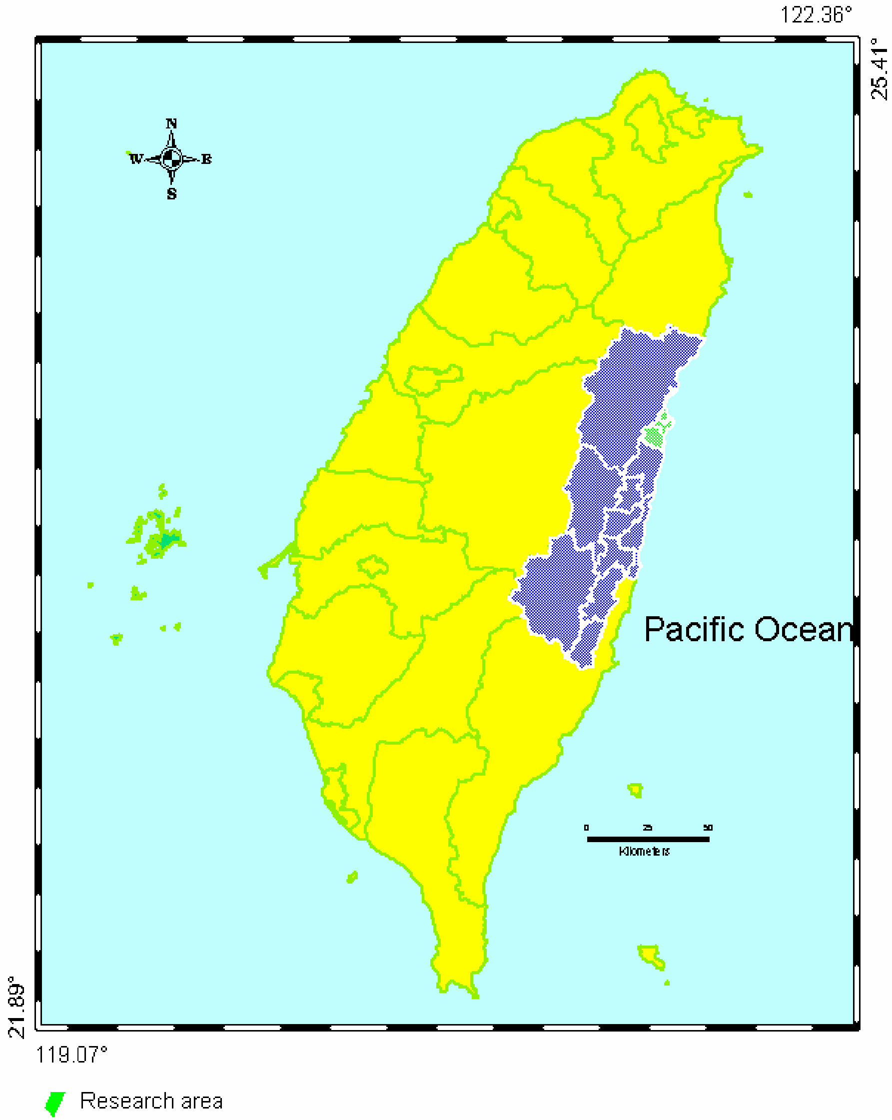


The Location of Water Well and Fault Distribution

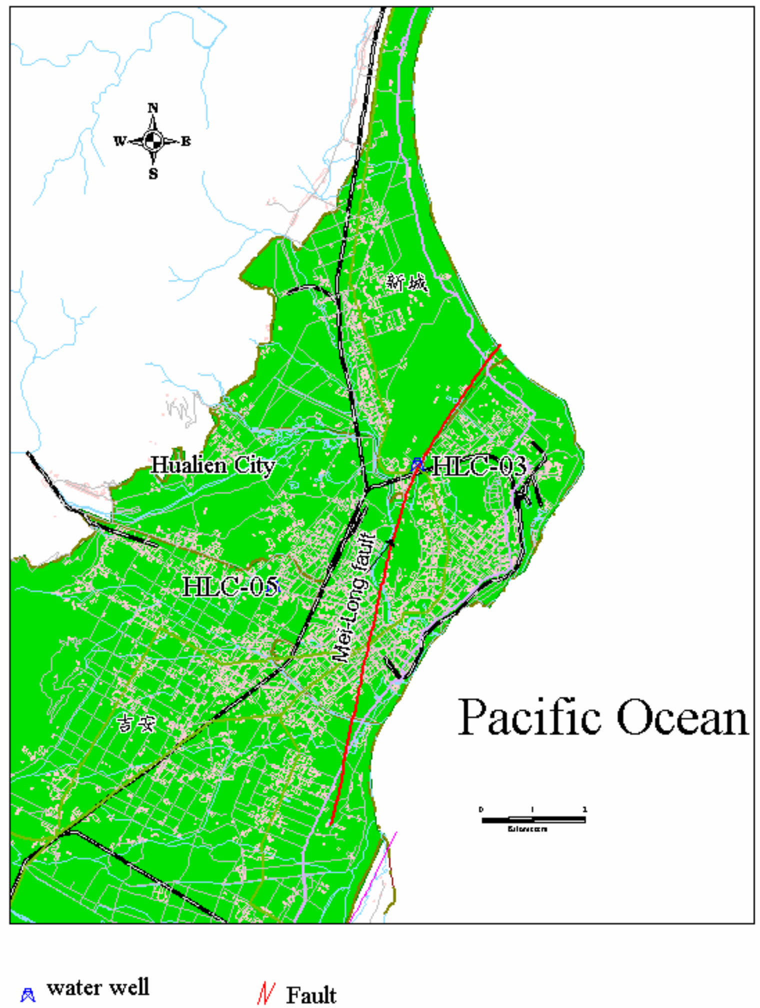


water well   Fault

Research Area Map



The Location of Water Well and Fault Distribution



Recording System for Water Level

General:

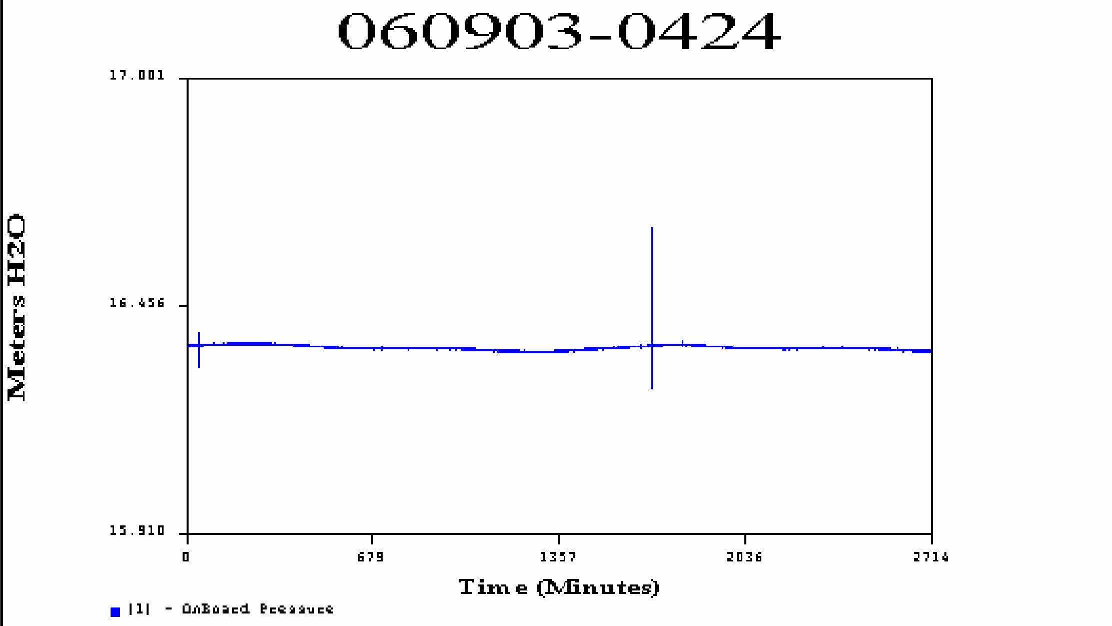
	Internal Power Model	External Power Model
Dimensions	18.3 mm (0.72 in) OD, 295.9 mm (11.65 in) long	18.3 mm (0.72 in) OD, 197.4 mm (7.77 in) long
Weight (includes backshell)	0.31 kg (0.68 lb) with batteries	0.22 kg (0.48 lb)
Wetted materials	316 stainless steel, Viton®, FEP* or polyurethane (cable), both models	
Resolution	16-bit A-D converter	16-bit A-D converter

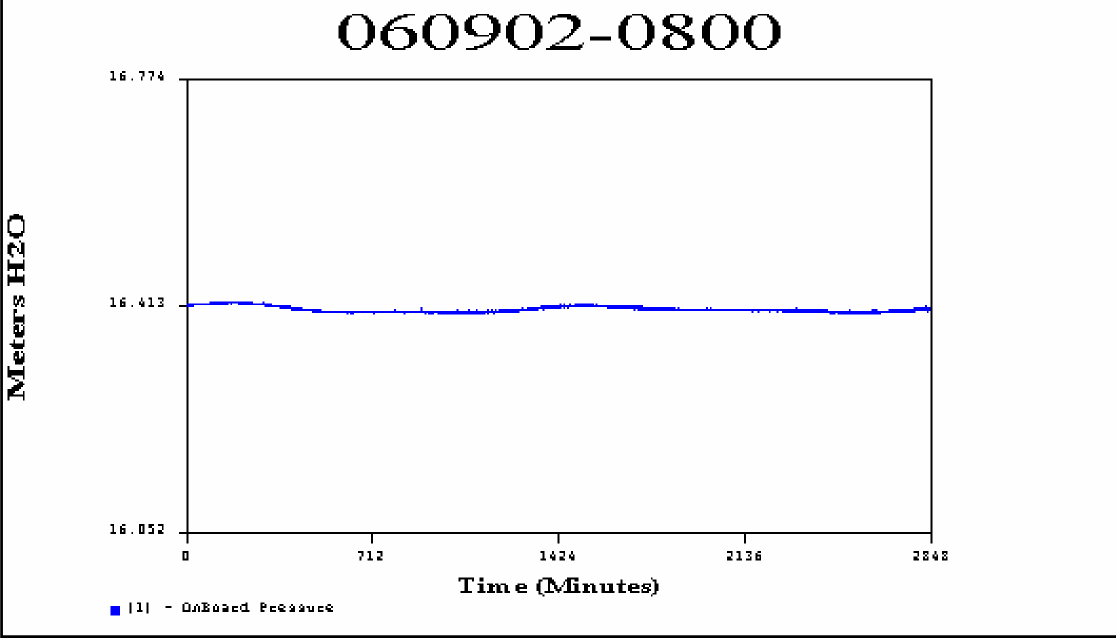
Sensors:

	Pressure Sensor	Temperature Sensor
Operating principle	integrated silicon strain-gauge pressure sensor	silicon temperature sensor
Ranges / Accuracies	11 m, 35 ft (103.4 kPa, 15 psi) / ±0.2% of FS 21 m, 69 ft (206.8 kPa, 30 psi) / ±0.1% of FS 70 m, 231 ft (689.5 kPa, 100 psi) / ±0.05% of FS 211 m, 692 ft (2068 kPa, 300 psi) / (call for info.)	-5 °C to 50 °C (23 °F to 122 °F) / ±0.25 °C
Pressure rating	2x range/3x burst (11 m = 3x range/5x burst)	NA
Operating temperature	-5 °C to 50 °C (23 °F to 122 °F)	-5 °C to 50 °C (23 °F to 122 °F)
Measurement schedules	linear (0.5 sec. minimum), logarithmic or event	linear (0.5 sec. minimum), logarithmic or event

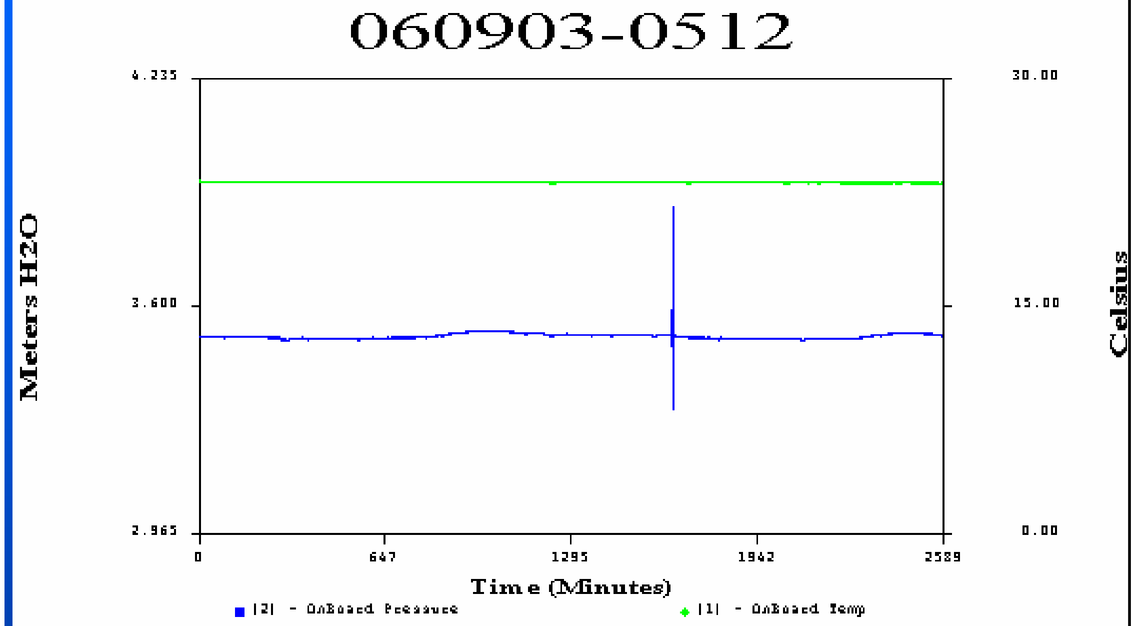
Sample Records of Water Level Change from Two Wells in Hualien

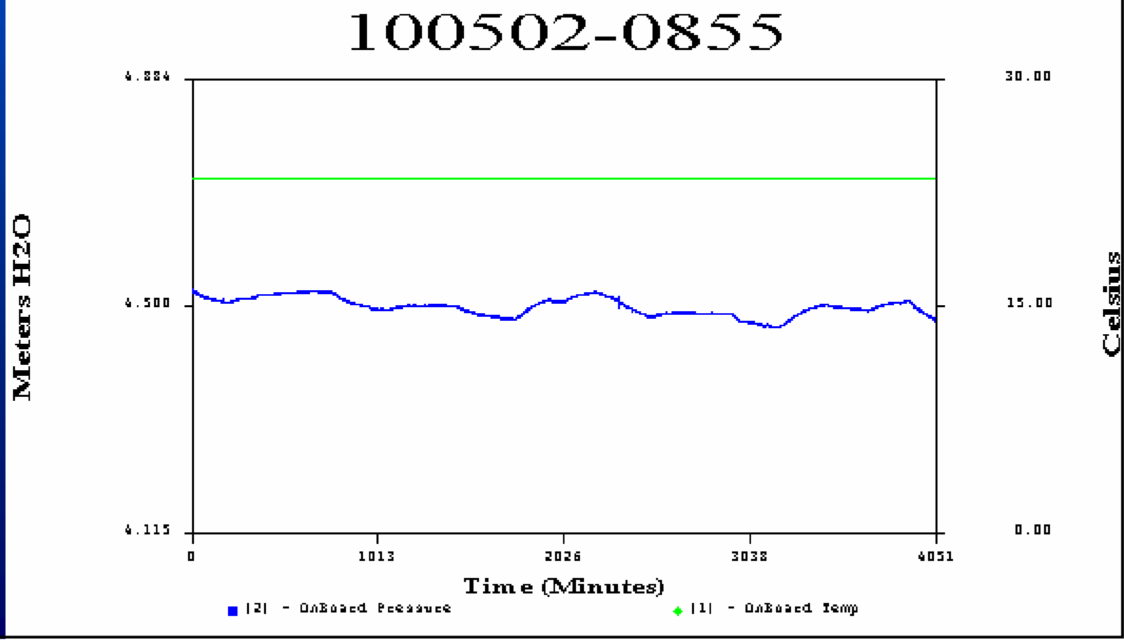
HLC-03





HLC-05

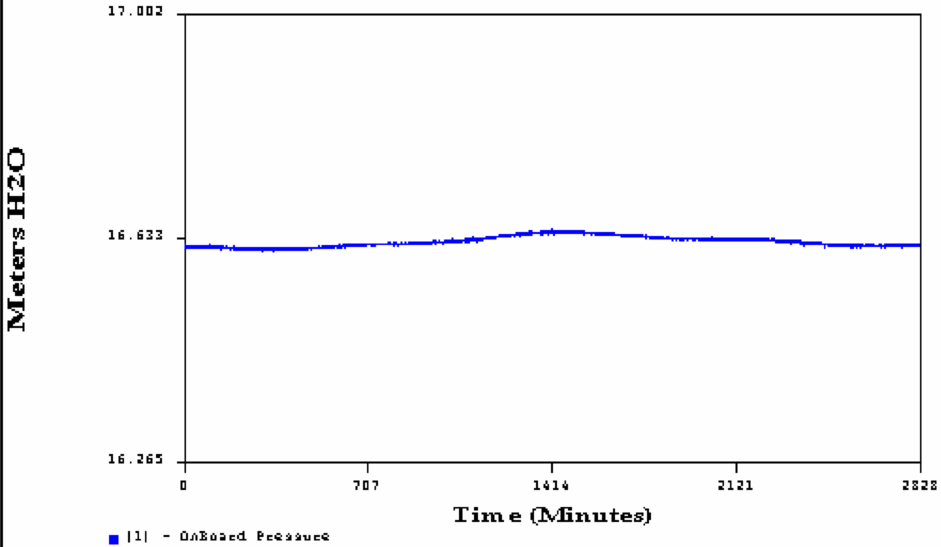




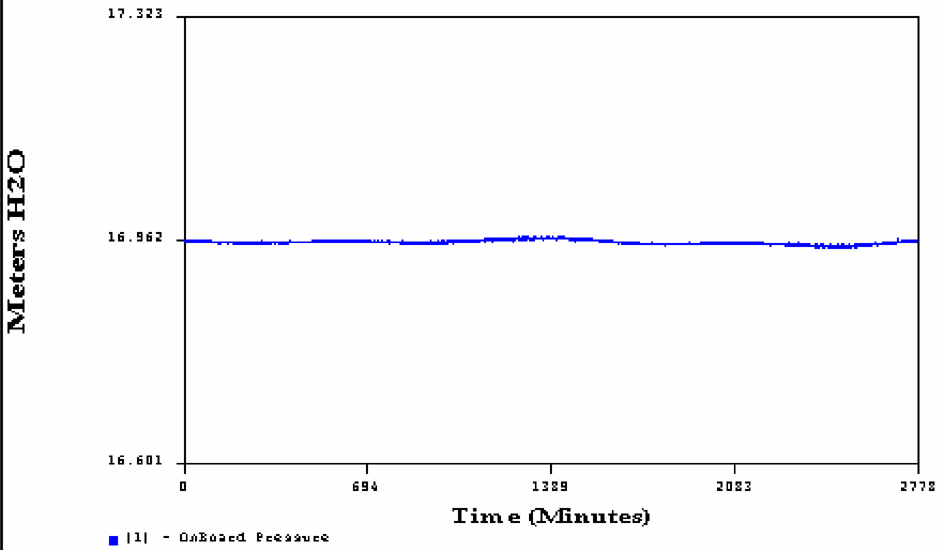
Sample Records of Water Level Change from Two Wells in Hualien

HLC-03

032302-1637

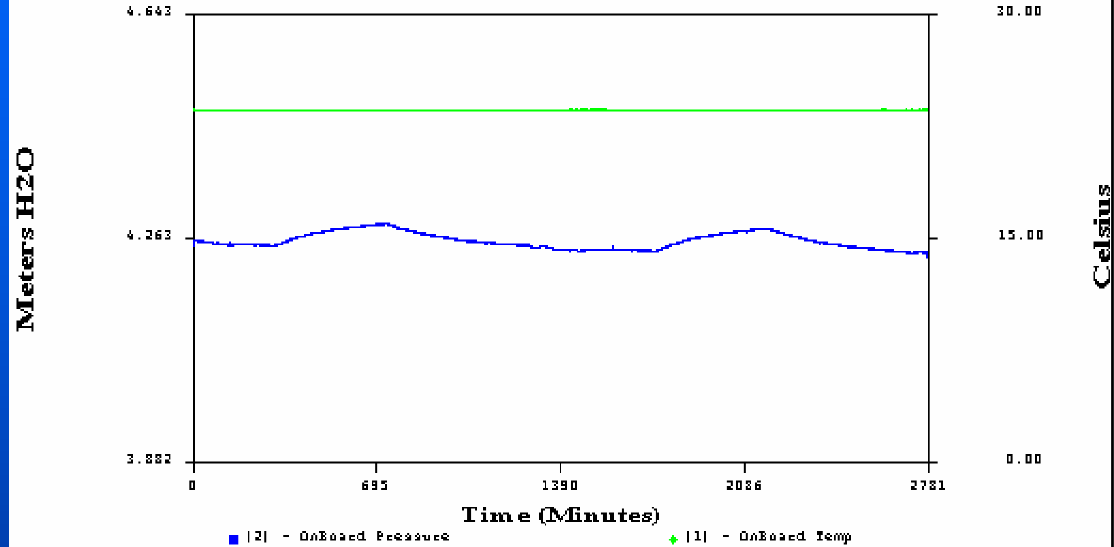


071802-0925

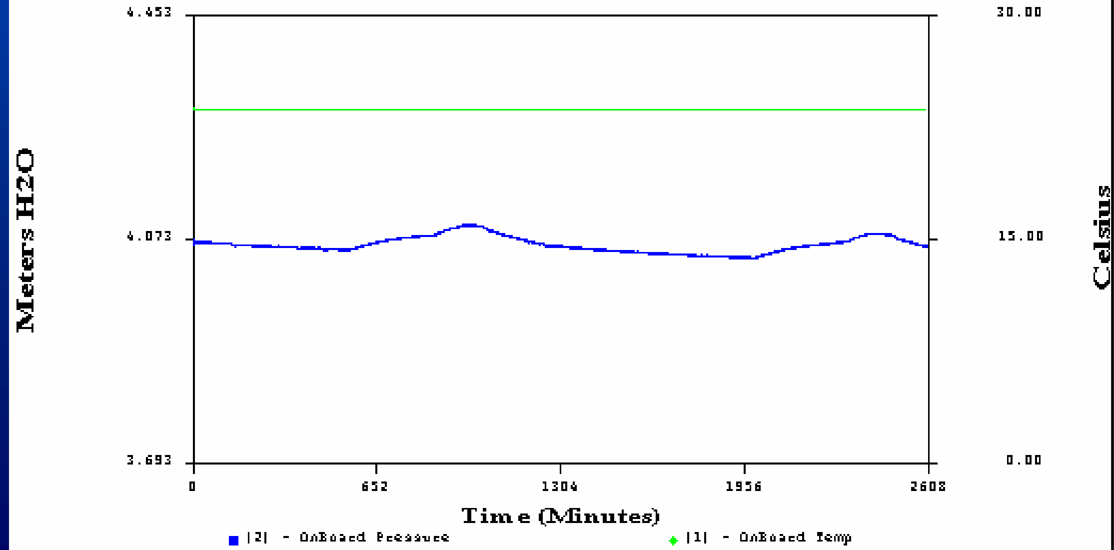


HLC-05

112802-0924

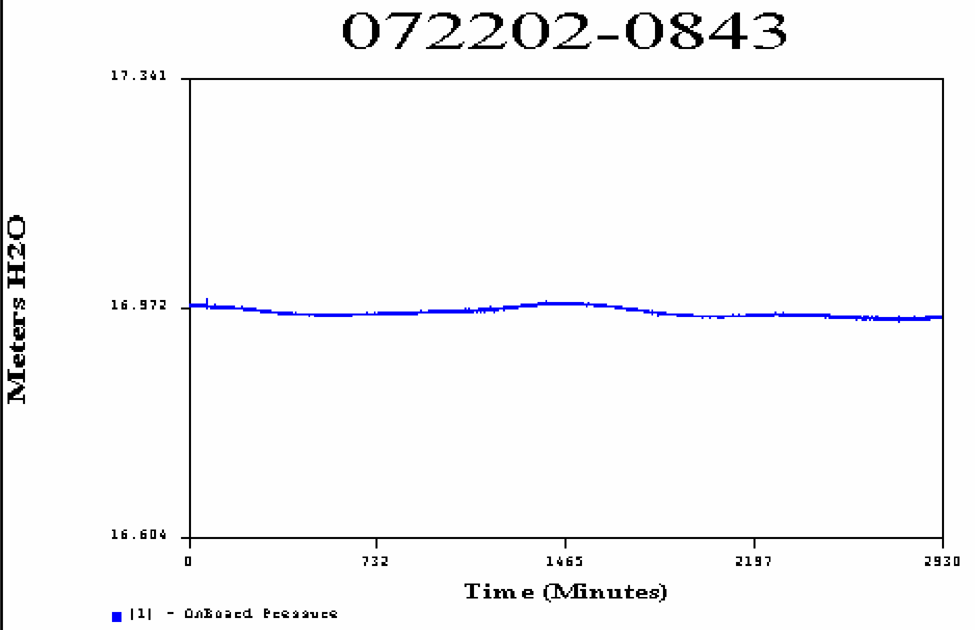


121602-0525

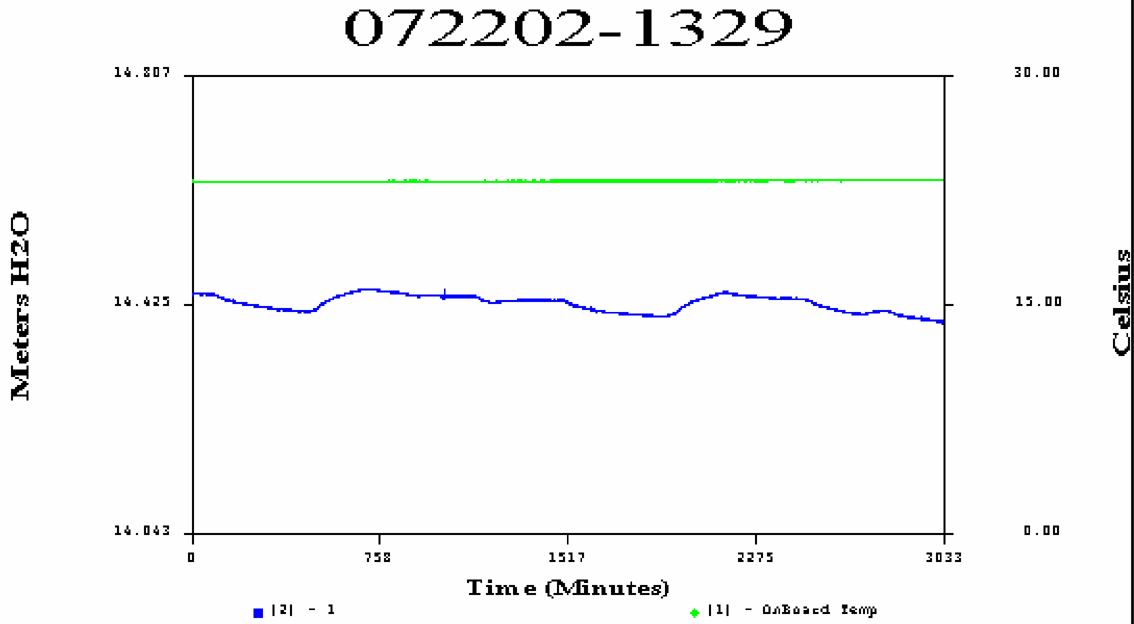


Daily Changes at Two Wells

HLC-03



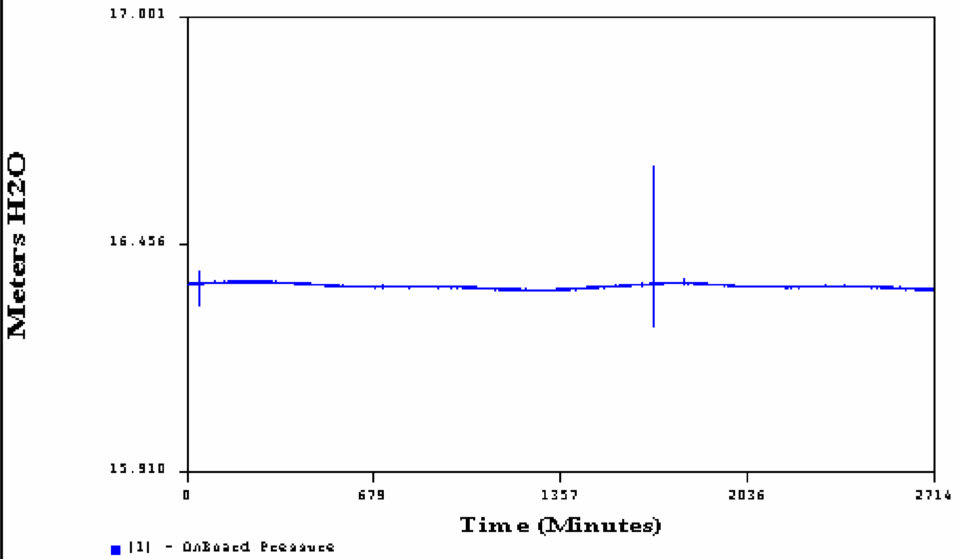
HLC-05



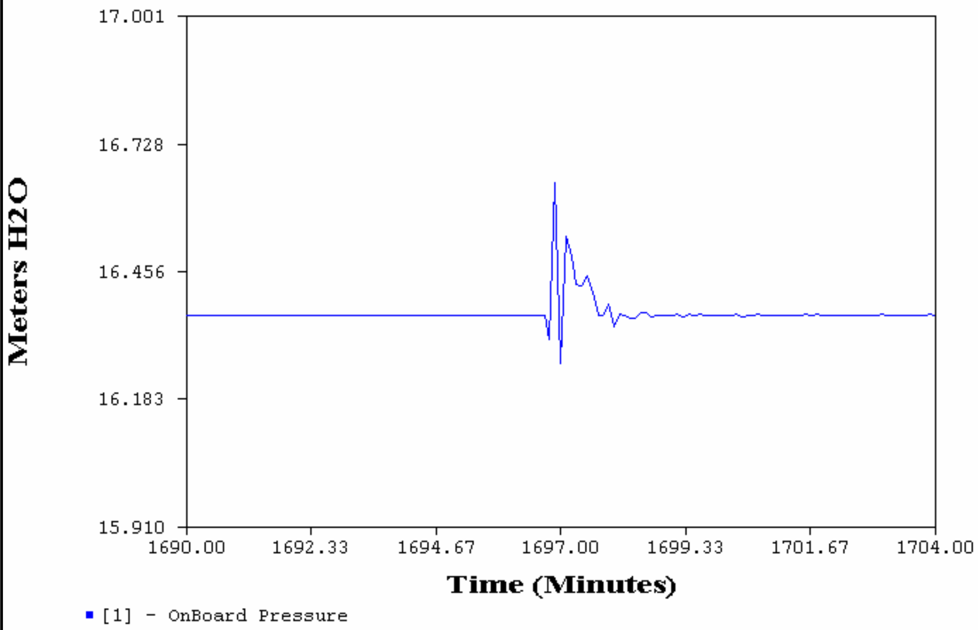
Sample Records of Water Level Changes due to an Earthquake on June 10, 2003

HLC-03

060903-0424

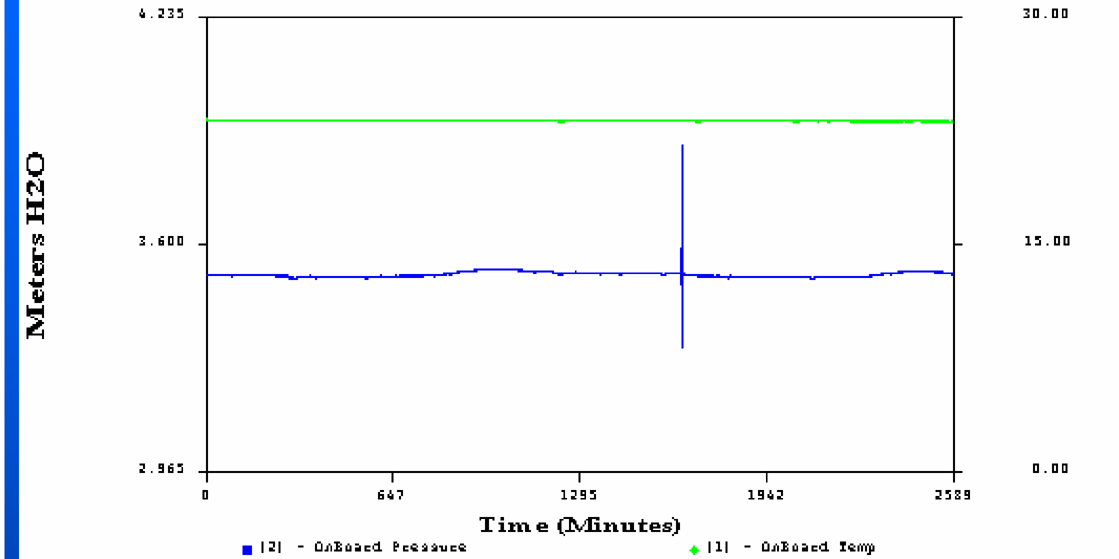


060903-0424

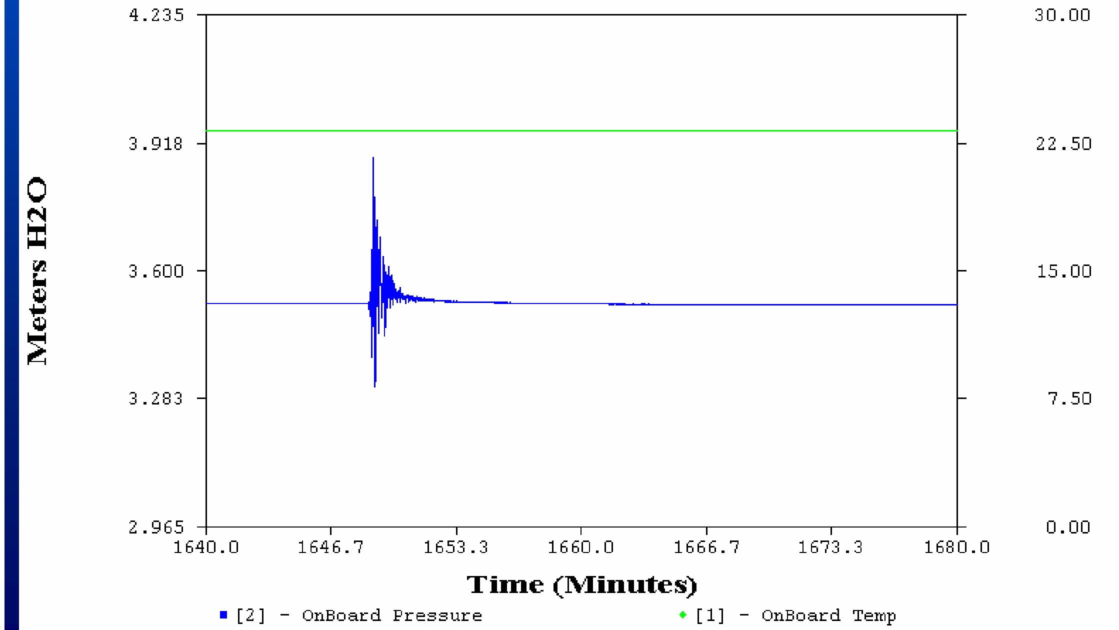


HLC-05

060903-0512

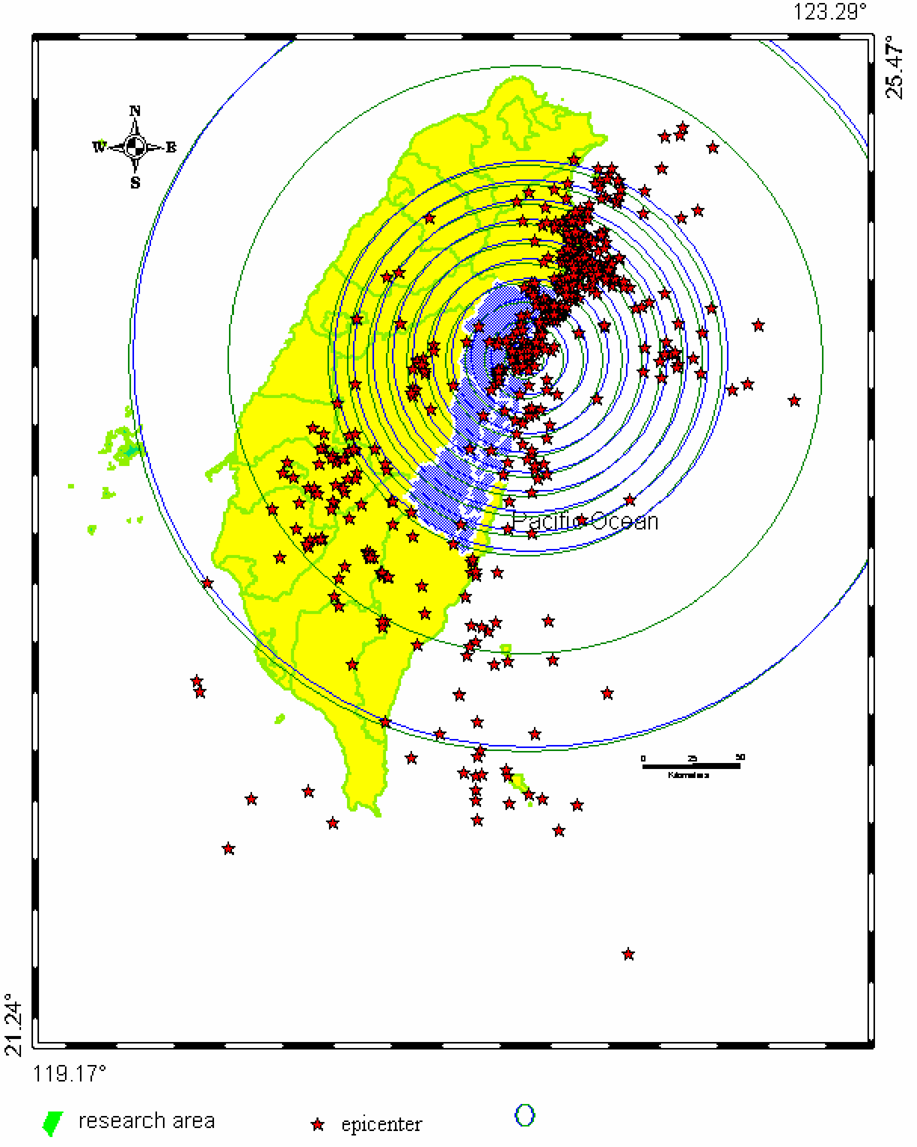


060903-0512

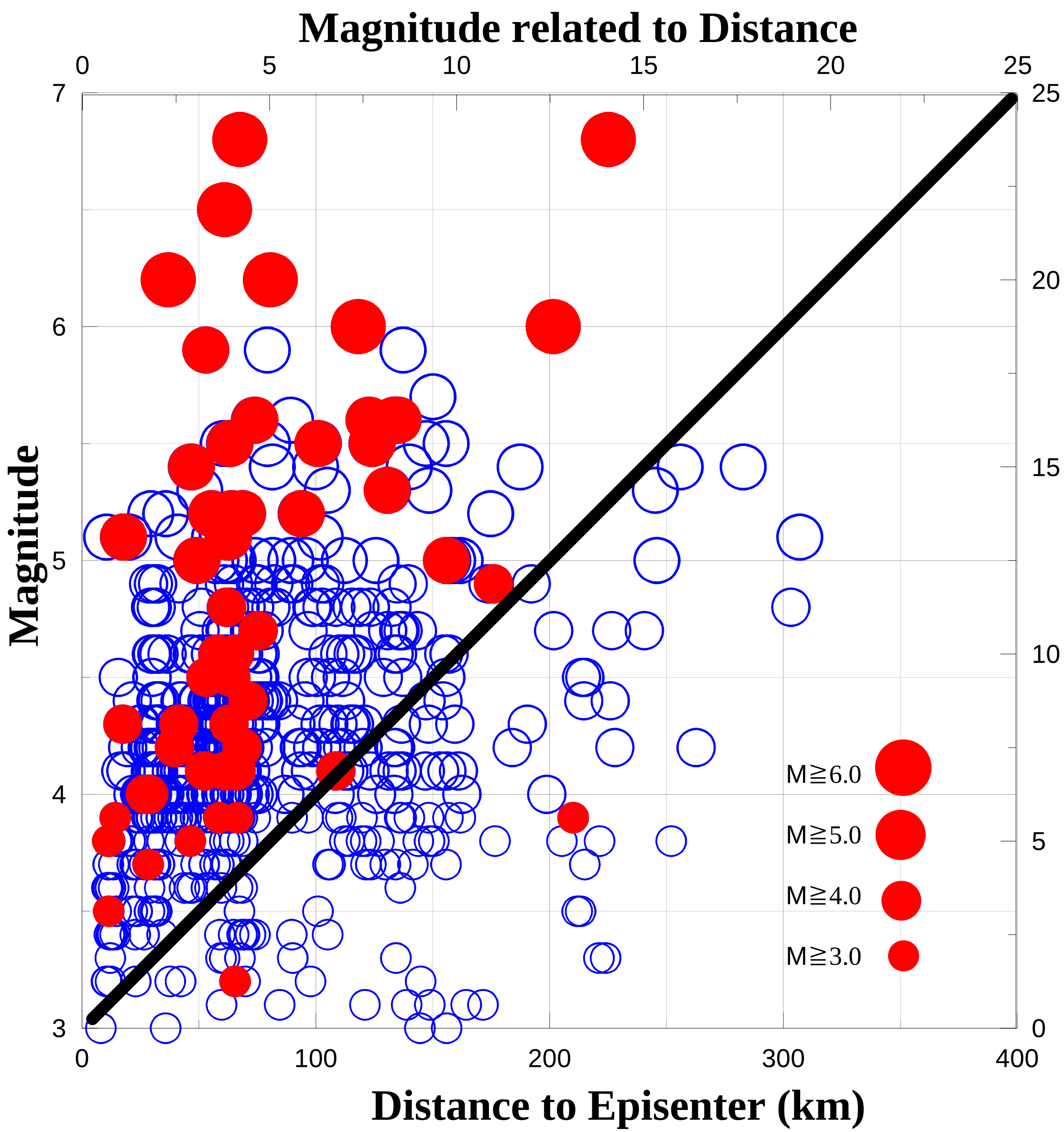


Earthquake Distribution

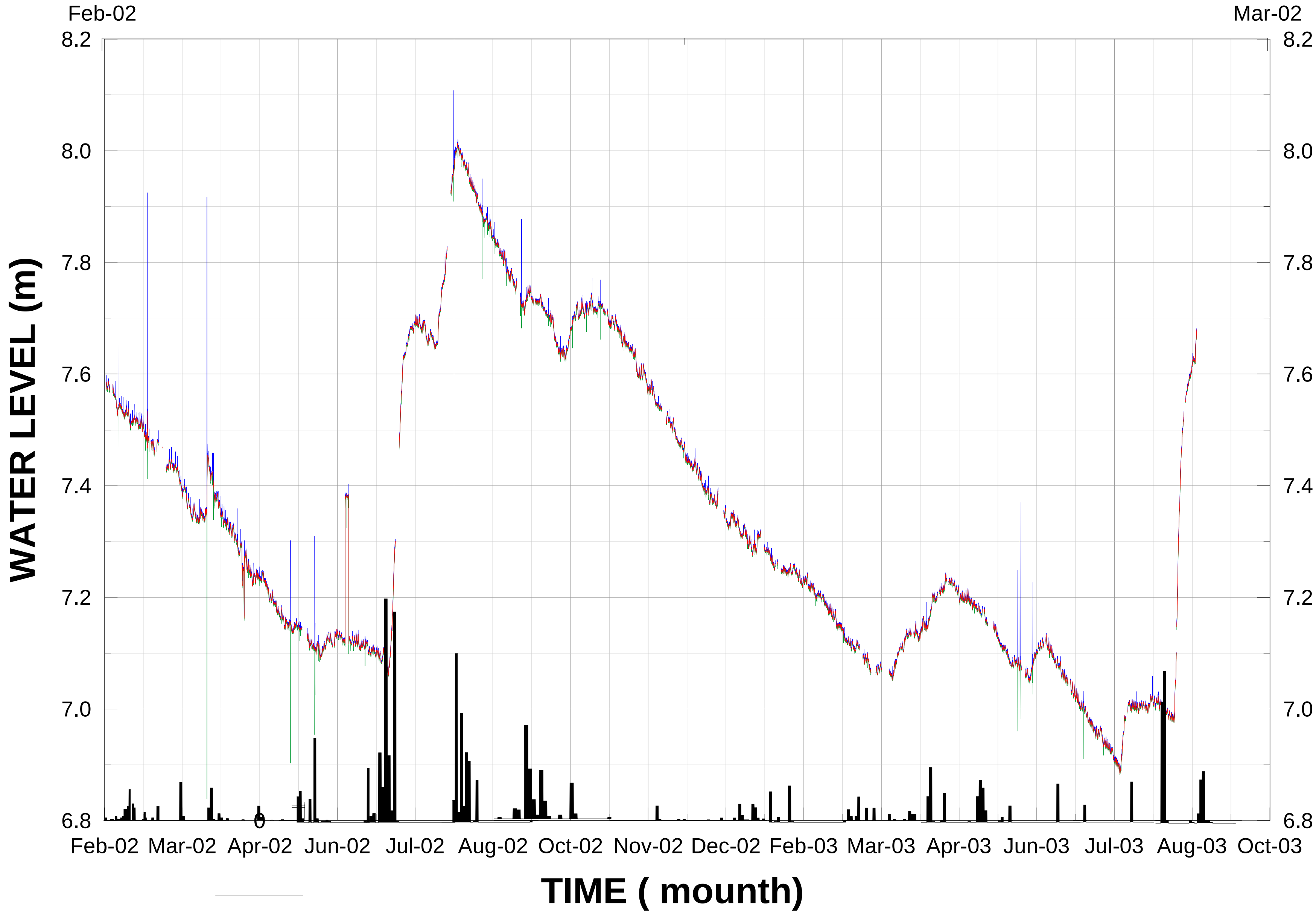
Epicenter Related to Wells Map



Observed Water Level Changes Related to Earthquake Magnitude and Distance

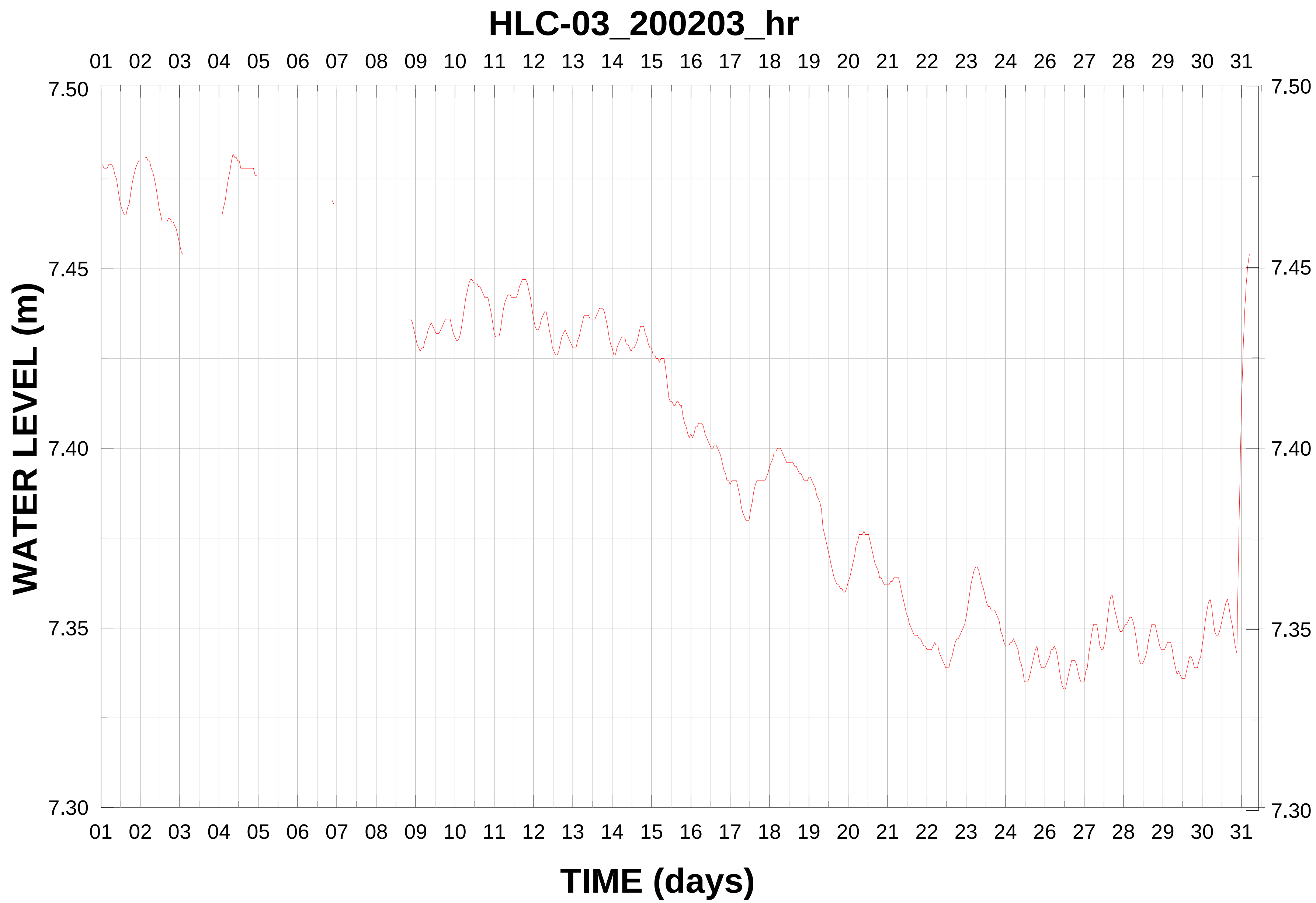


Long-Term Water Level Changes at HLC-03

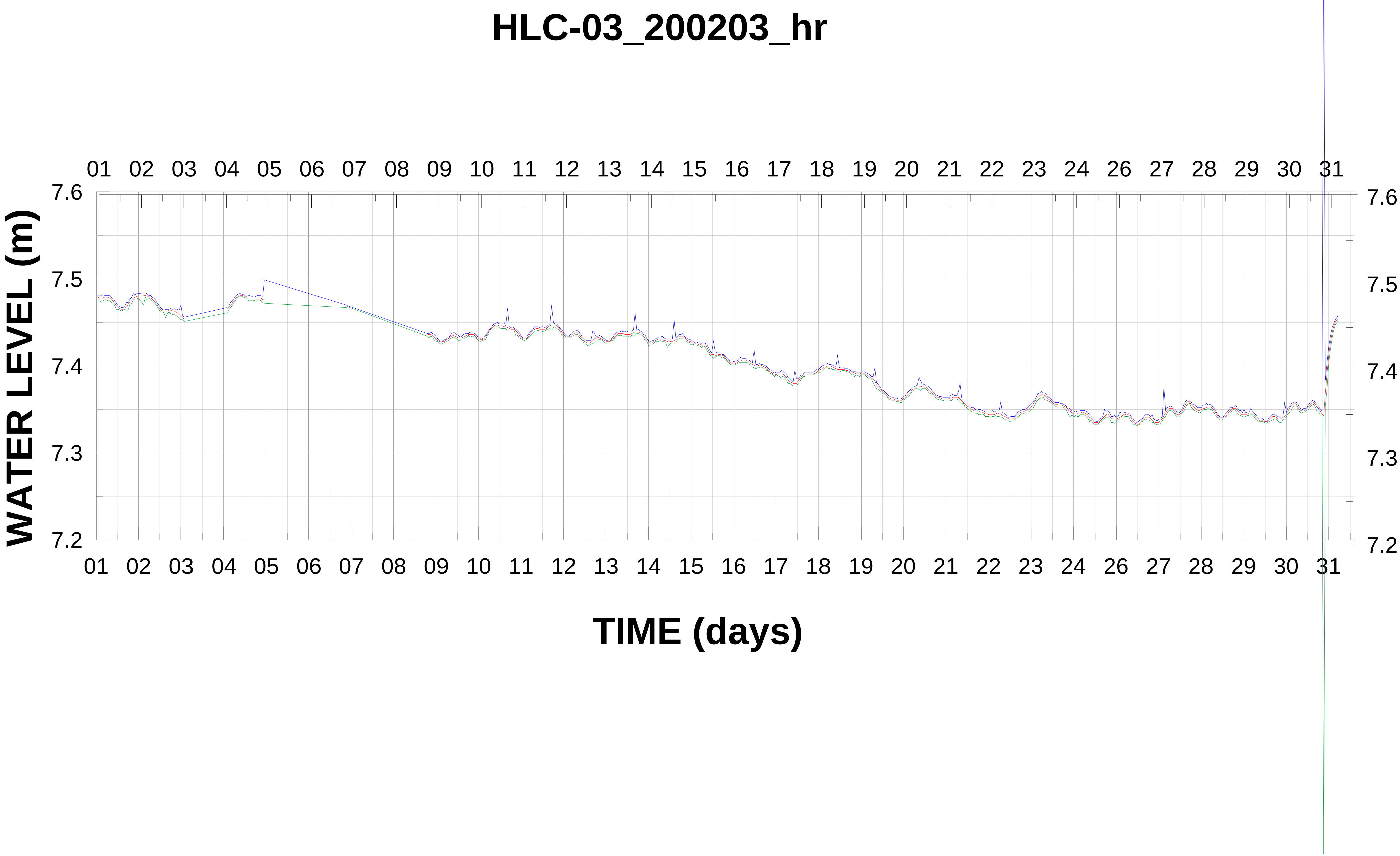


Long-Term Water Level Changes at HLC-03

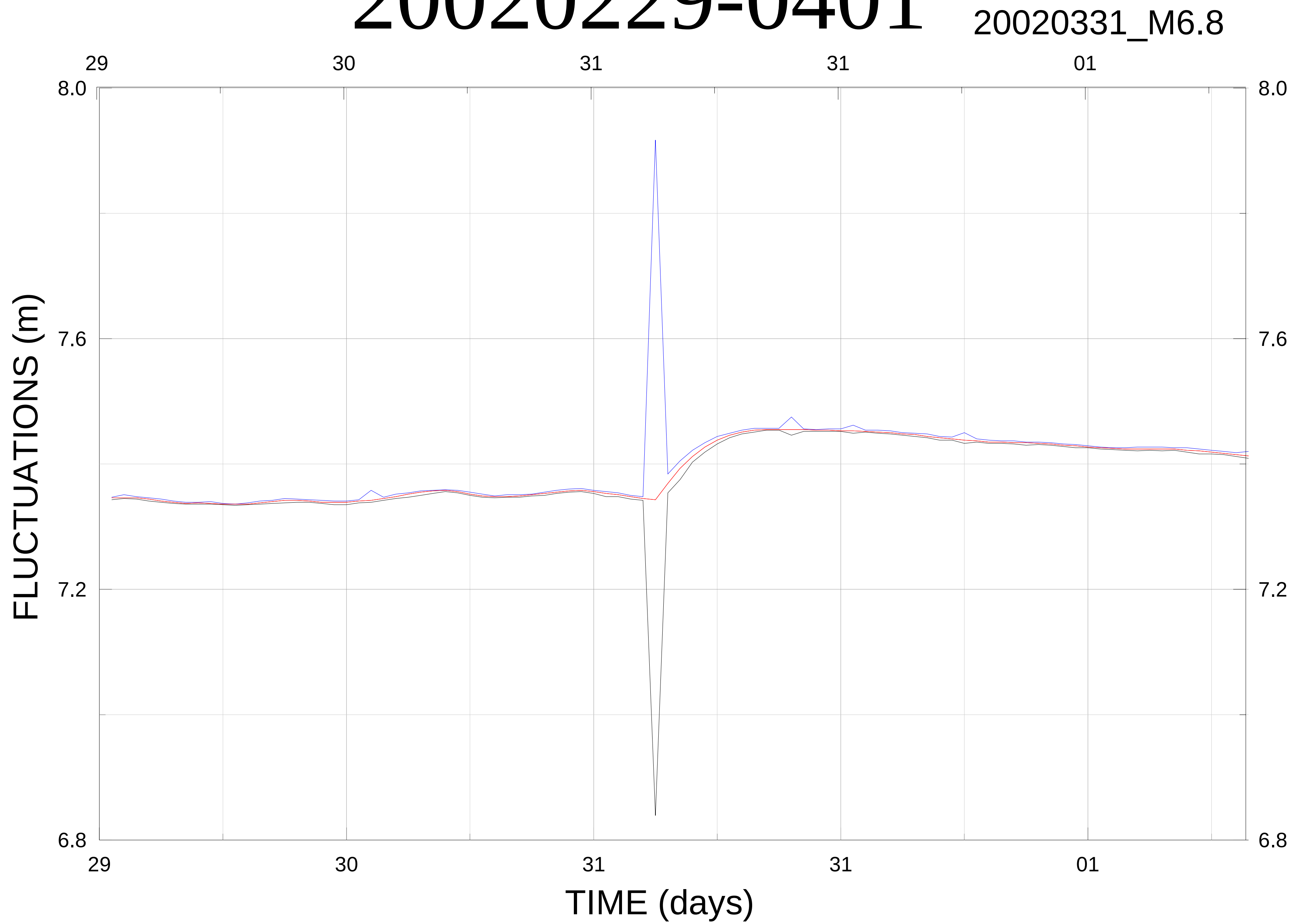
Month



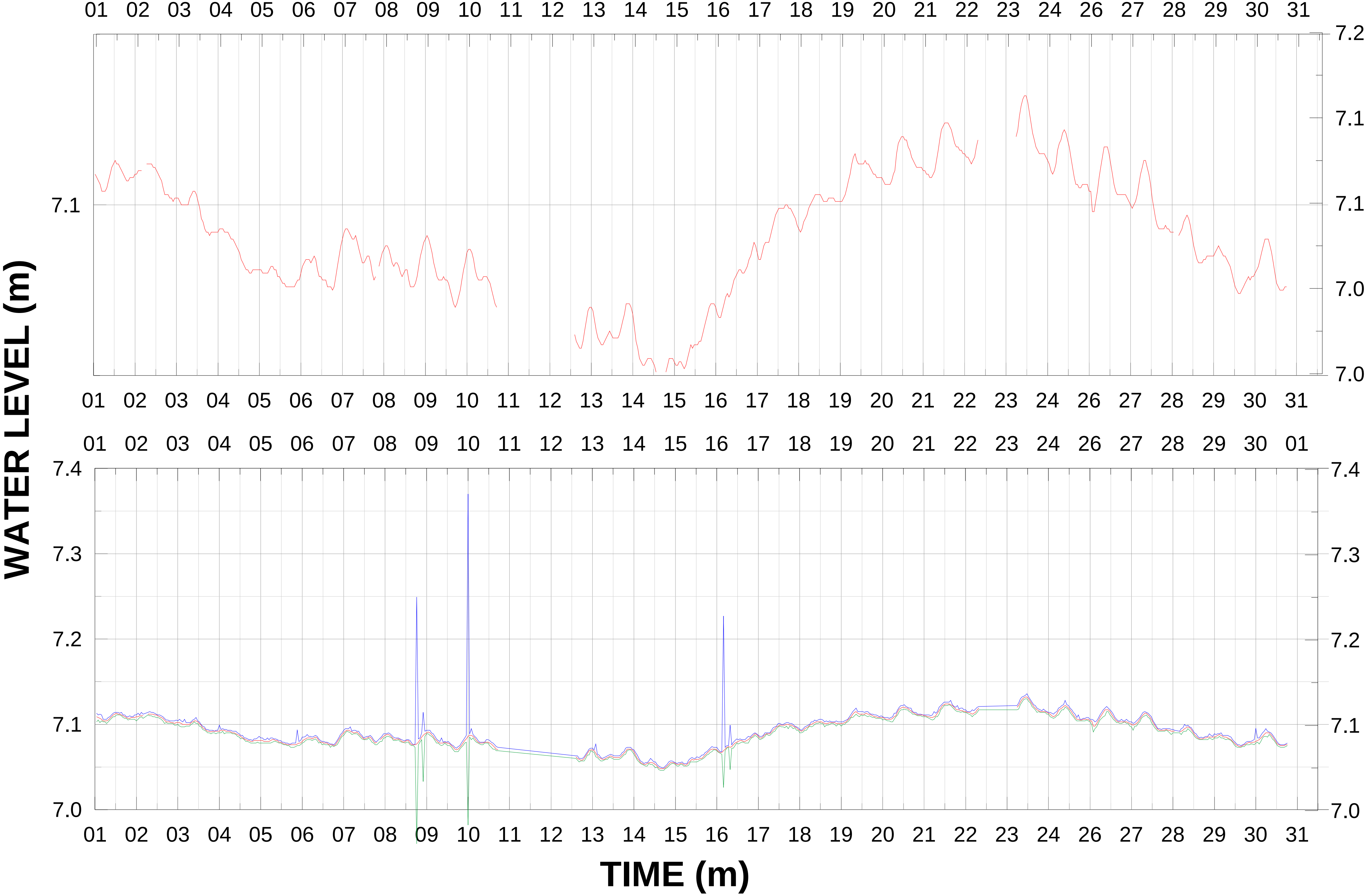
The Long-Term Water Level Changes

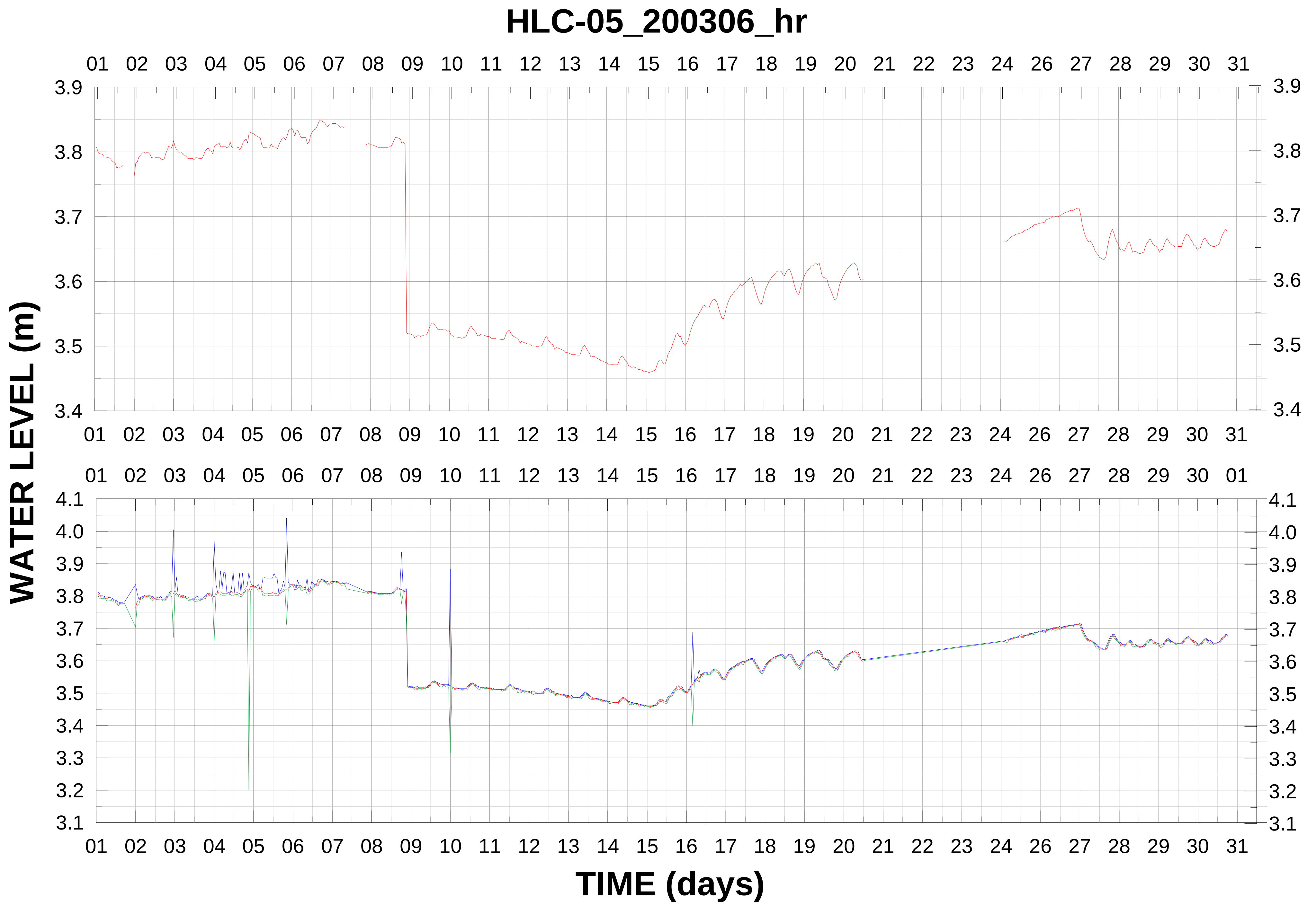


The Water Level Changes on 20020229-0401

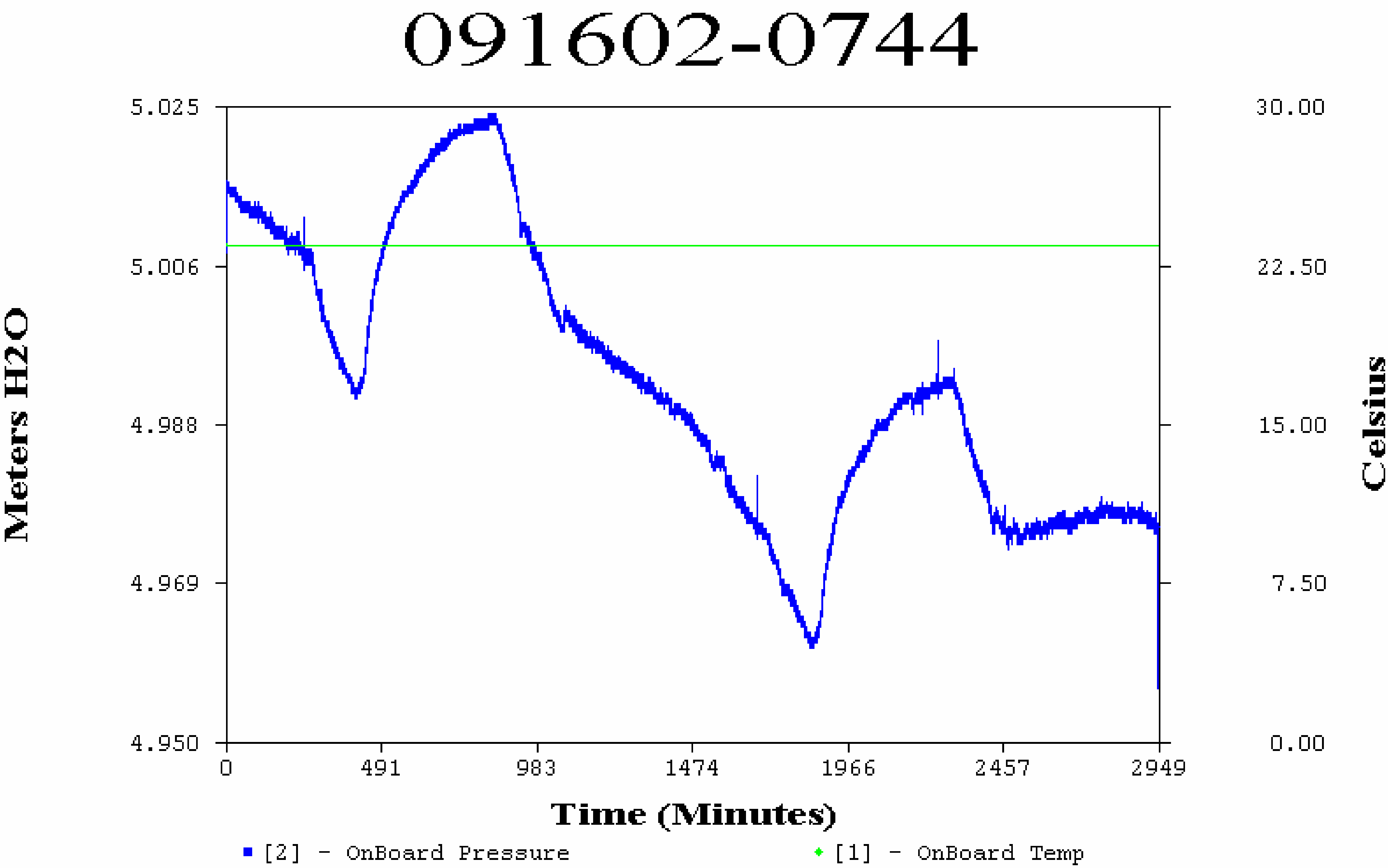


HLC-03_200306_hr



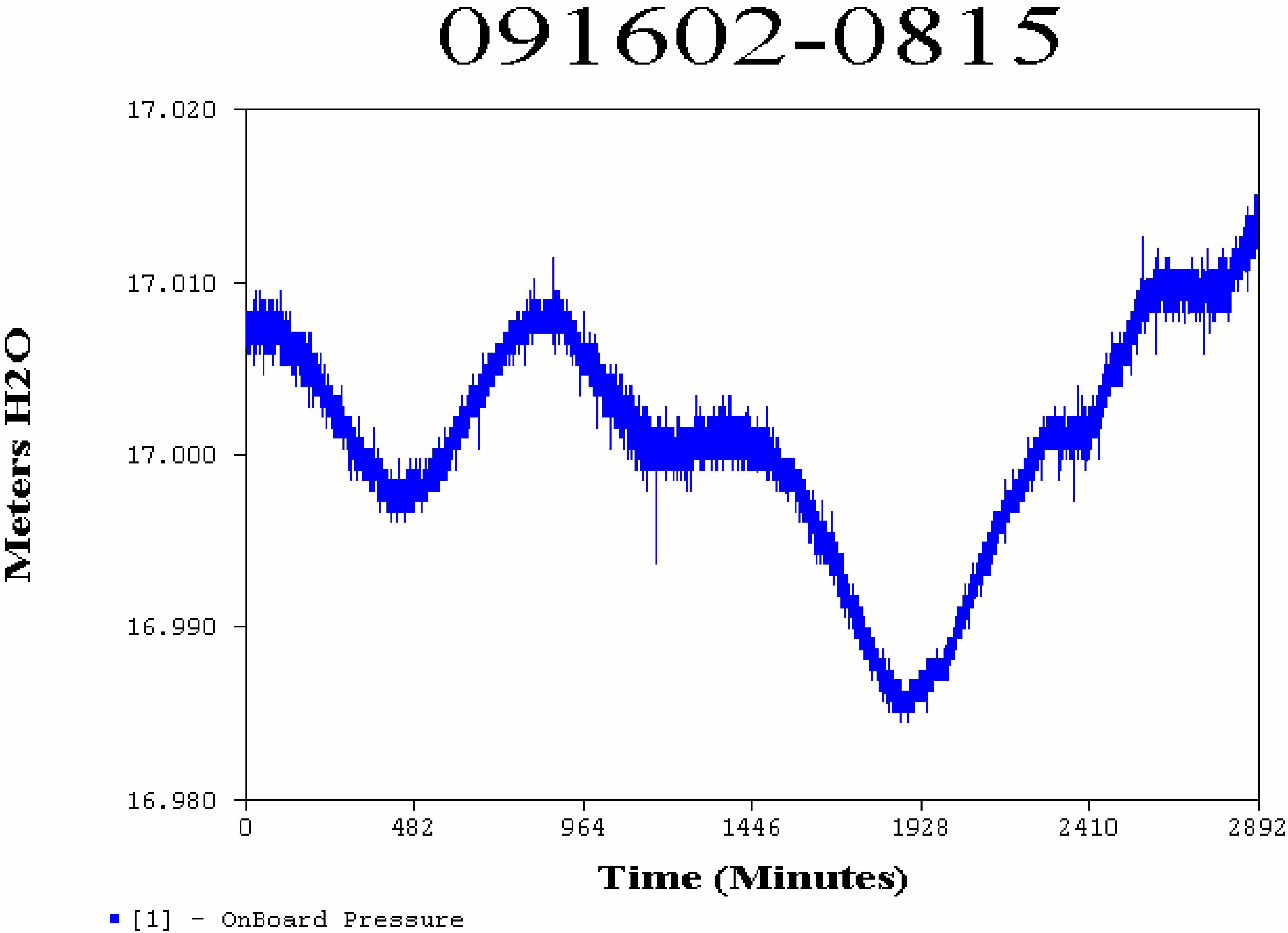

HLC-05_200306_hr
WATER LEVEL (m)
TIME (days)

Raw Data

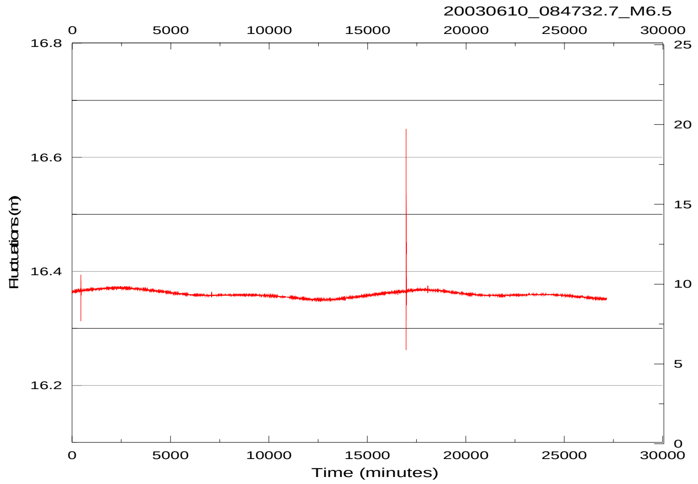


091602-0744
5.025
5.006
4.988
4.969
4.950
30.00
22.50
15.00
7.50
0.00
Meters H2O
Celsius
0
491
983
1474
1966
2457
2949
Time (Minutes)
[2] - OnBoard Pressure
[1] - OnBoard Temp

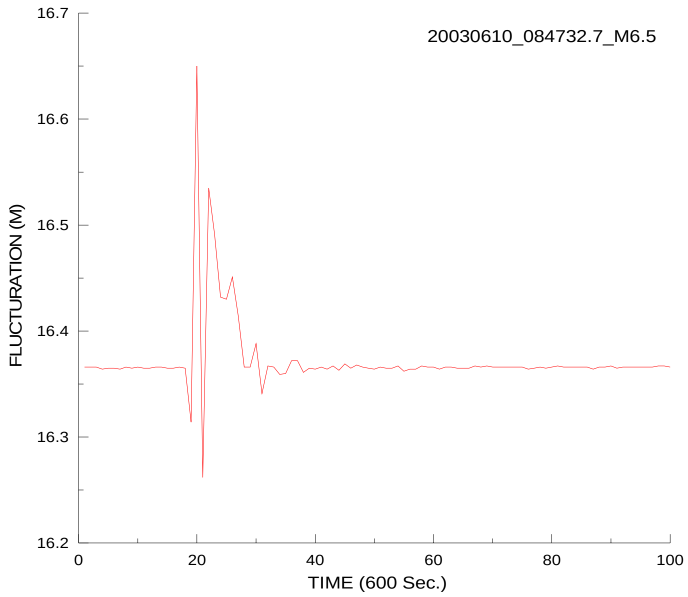
Raw Data


091602-0815
17.020
17.010
17.000
16.990
16.980
Meters H2O
0
482
964
1446
1928
2410
2892
Time (Minutes)
[1] - OnBoard Pressure

HLC-03

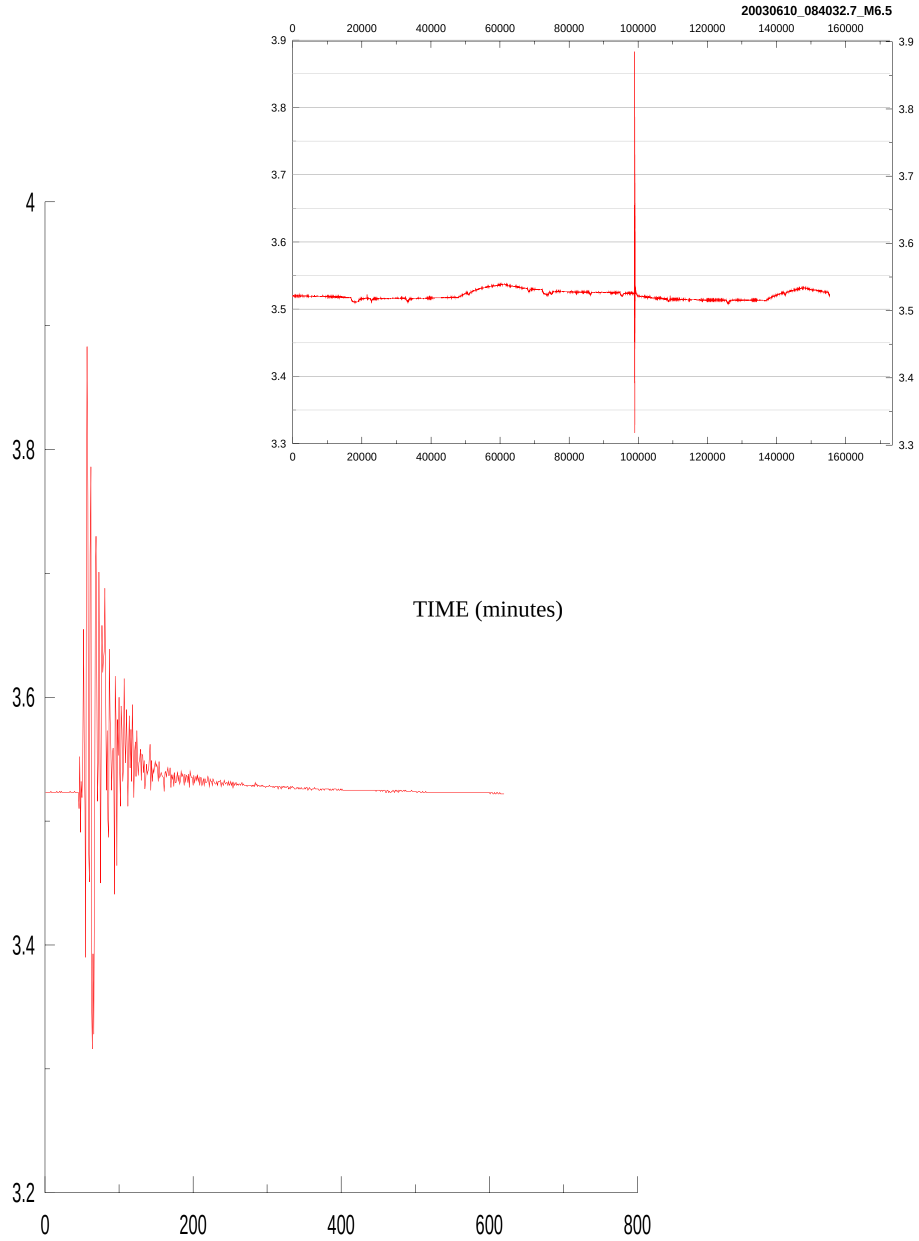


20030610_084732.7_M6.5
Fluctuations(m)
Time (minutes)

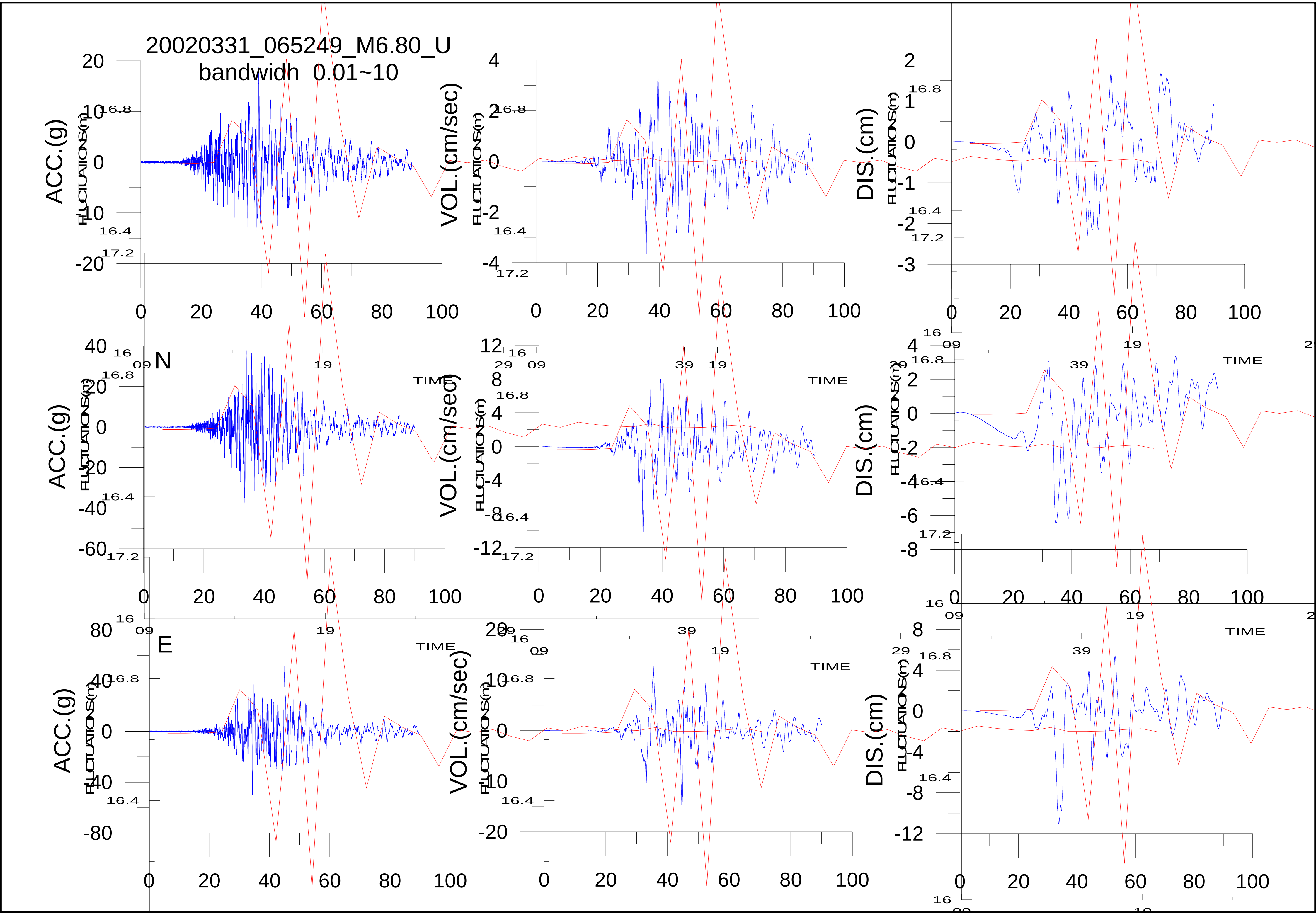


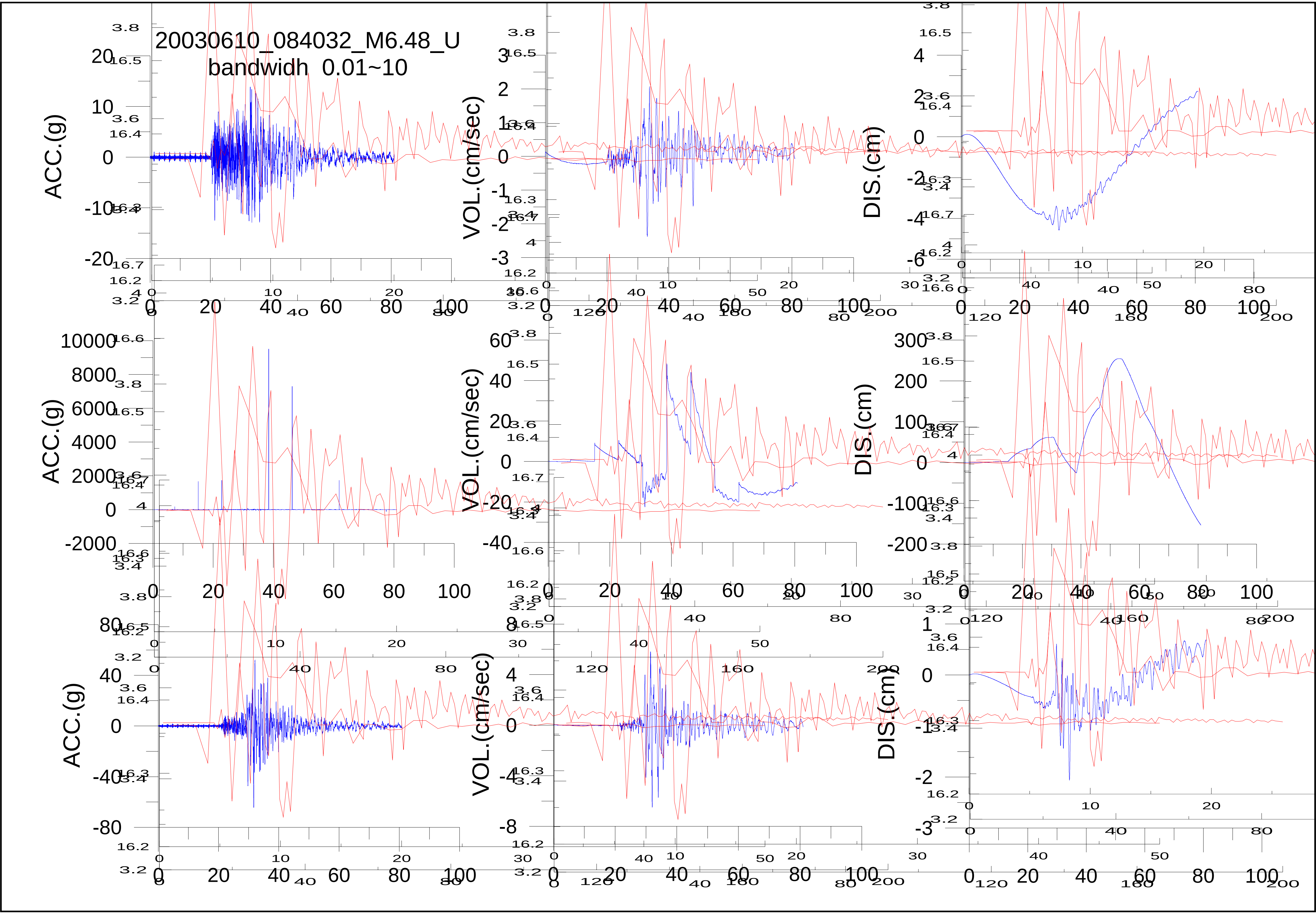
20030610_084732.7_M6.5
FLUCTURATION (M)
TIME (600 Sec.)

HLC-05



20030610_084032.7_M6.5
TIME (minutes)


20020331_065249_M6.80_U
bandwidh 0.01~10
N
E
ACC.(g)
VOL.(cm/sec)
DIS.(cm)
FLUCTUATIONS(m)
TIME


20030610_084032_M6.48_U
bandwidh 0.01~10
ACC.(g)
VOL.(cm/sec)
DIS.(cm)

Preliminary Conclusions

- Coseismic groundwater level changes (GLC) are observed from many, but not all, earthquakes in Hualien and surrounding areas.
- Both static and vibratory GLC are observed from the recods. They are due to rupture-induced crustal strain changes and passing seismic waves, respectively.
- Comparison of GLC records with seismic records is in progress.

Thank you for your attention