112-2 Seminar

Groundwater Level Anomalies in Various Depths Relate to Earthquakes in the Milun Fault Observation System, Hualien

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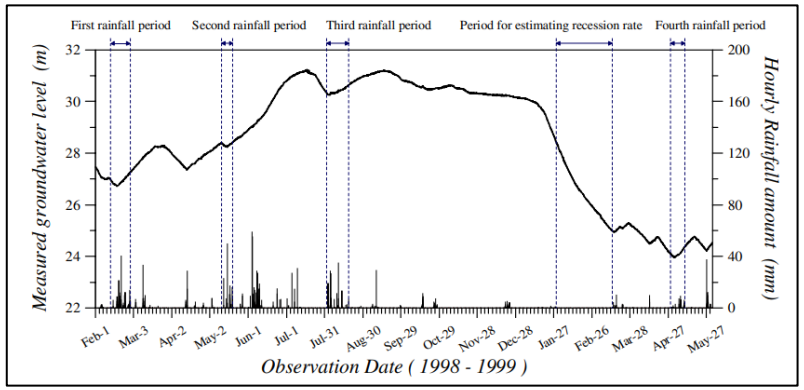
Advisor: Prof. Shih-Jung Wang

Date:2024/04/19

Introduction

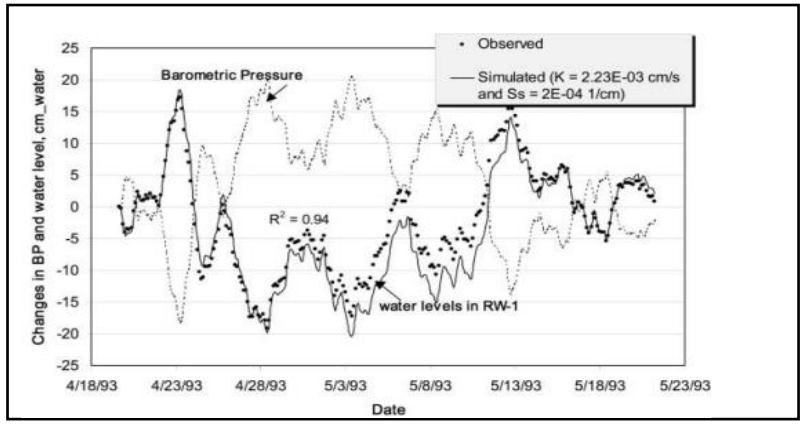
Groundwater Level Changes Characteristics

Rain



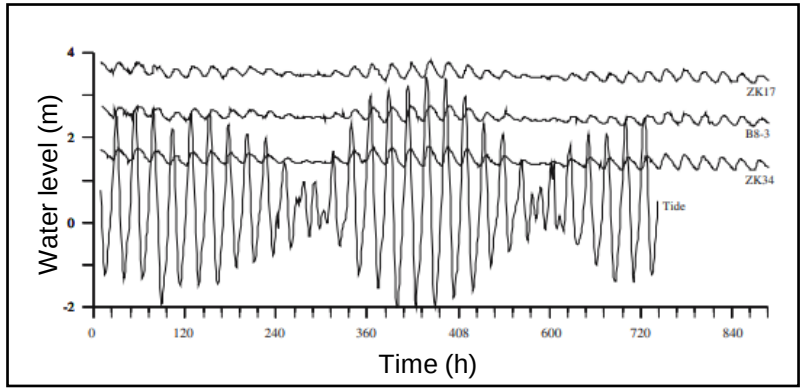
Rainfall as a recharge will lead to do gradually increase to the groundwater level **(Jan et al., 2007)**.

Barometric Pressure



An increase in barometric pressure will cause the groundwater level to show a declining trend (cross correlation) **(Seo, 2014)**.

Sea Tide

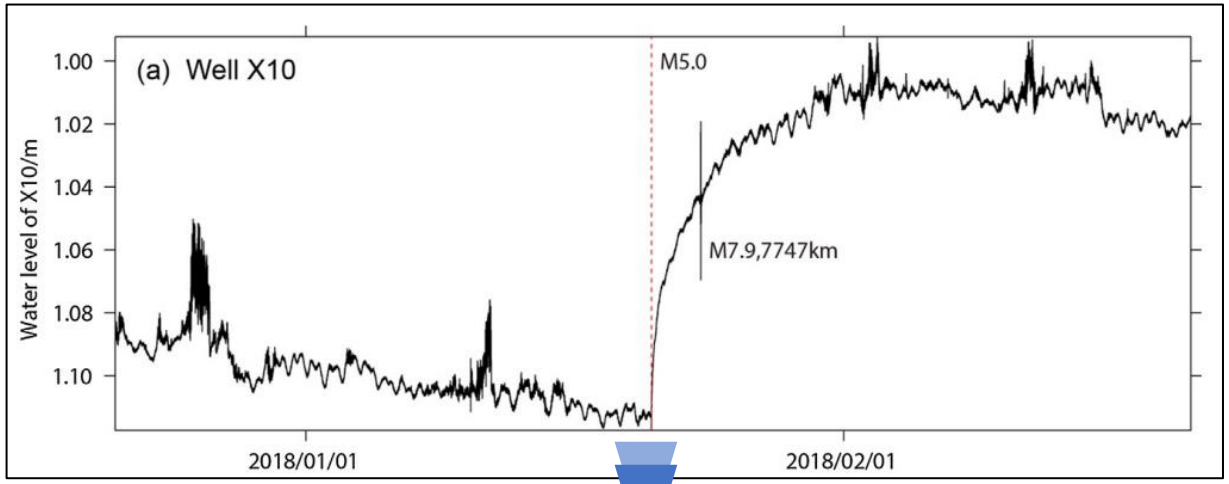


High tide increases coastal groundwater pressure, causing seawater intrusion and raising groundwater levels, while low tide reduces this pressure, decreasing groundwater levels **(Xun et al., 2006)**.

Groundwater Level Changes Characteristics

Groundwater level changes due to the 2018 M 5.0 Urumqi, China earthquake **(Orihara et al., 2014)**.

Earthquake

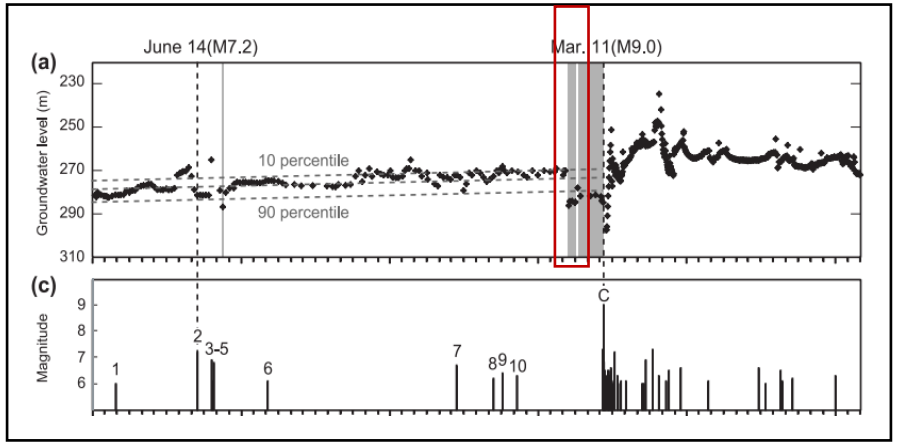


Abrupt Transition

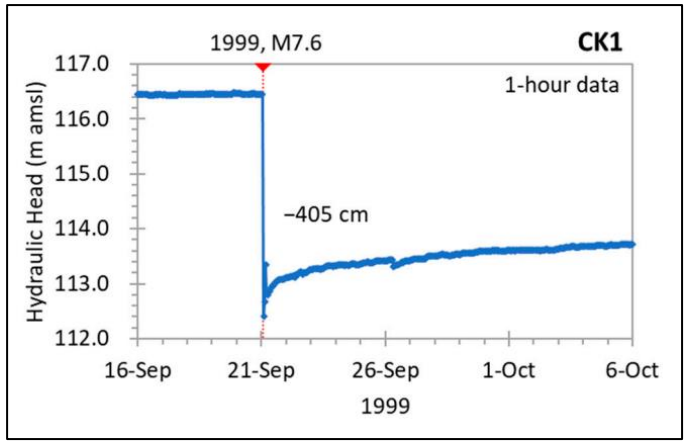
Anomaly

Earthquake Related Groundwater Level Anomaly

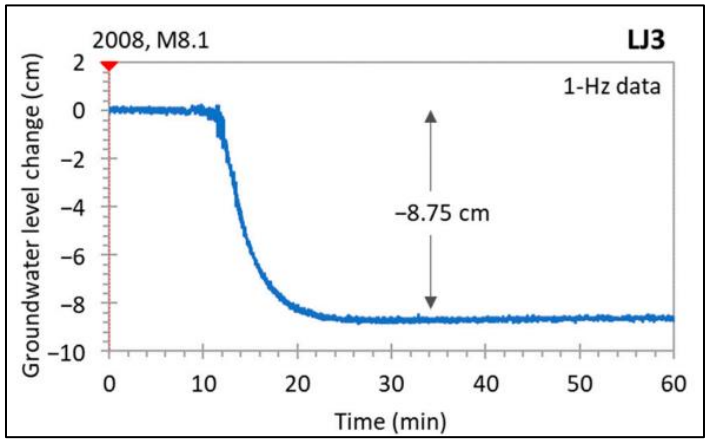
- The fluid in the crust is very sensitive to crust strain and solid deformation lead to the groundwater level changes in a well from the confined aquifer even if the deformation in the crust is small **(Shi et al., 2008)**.
- Earthquake related groundwater anomaly:
  - Pre-seismic
  - Co-seismic
  - Post-seismic



Anomalous groundwater changes started three months before 2011 M 9.0 off the pacific coast of the Tohoku Earthquake, Japan **(Orihara et al., 2014)**.



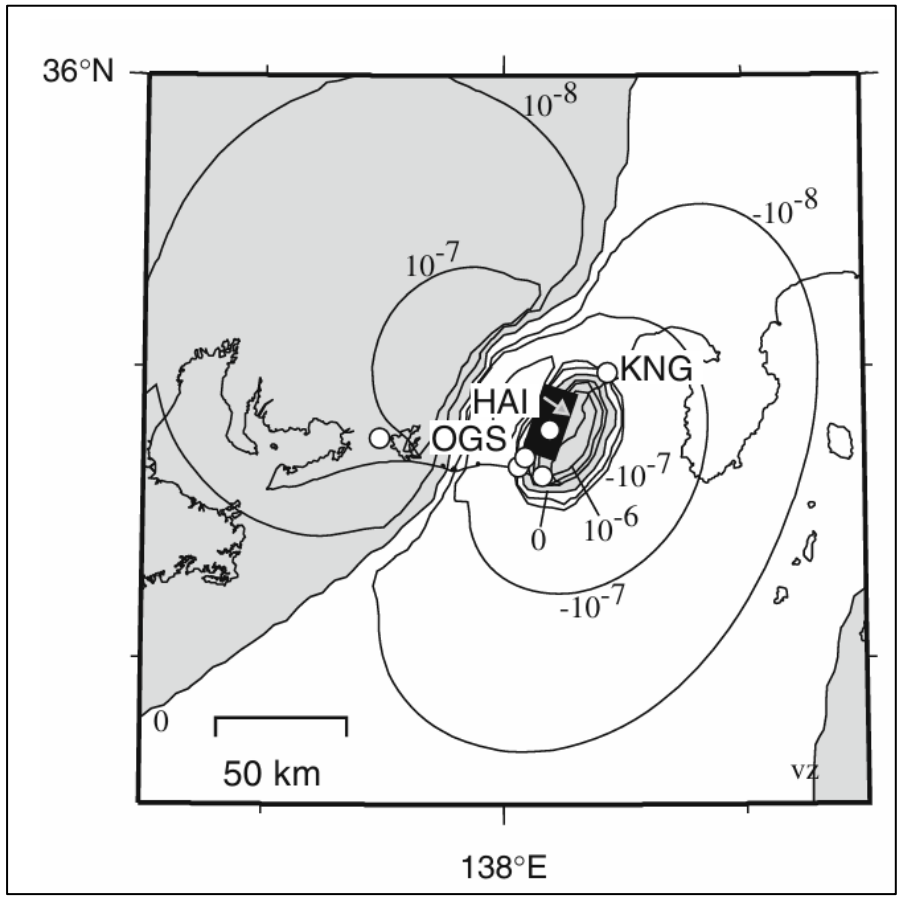
A co-seismic fall due to the 1999 M 7.6 Chi-Chi earthquake **(Liu et al., 2023)**.



Sustained changes recorded following the 2008 M 8.1 Wenchuan earthquake **(Liu et al., 2023)**.

Pre-slip Prior to an Earthquake

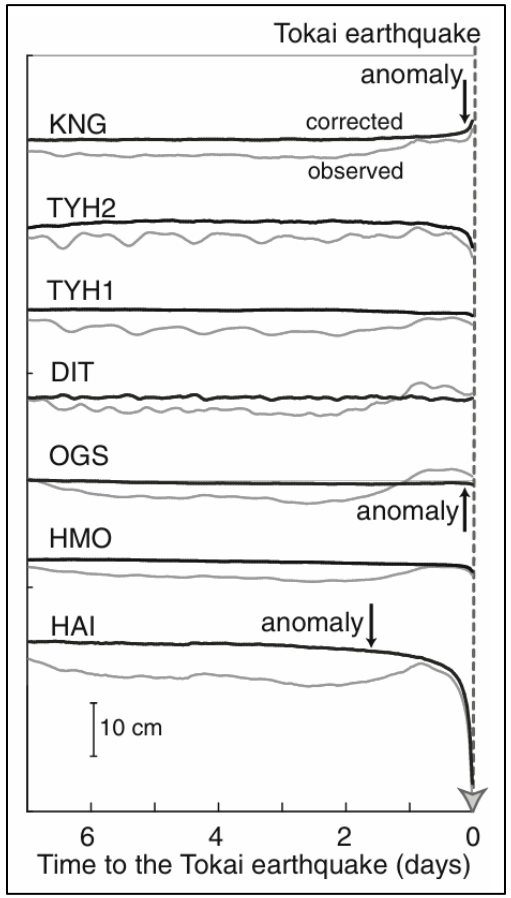
The relationship between pore pressure and strain is described by poroelastic theory **(e.g. Wang, 2000)**. If typical elastic and poroelastic constants are assumed, 10^{-6} contractional volumetric strain can produce a 1 m rise in groundwater level **(Roeloffs, 1996)**.



Estimated volumetric strain distribution in the Tokai region induced by a hypothetical Mw 6.5 aseismic pre-slip **(Matsumoto et al., 2007)**.

: Extensional strain

: Contractional strain



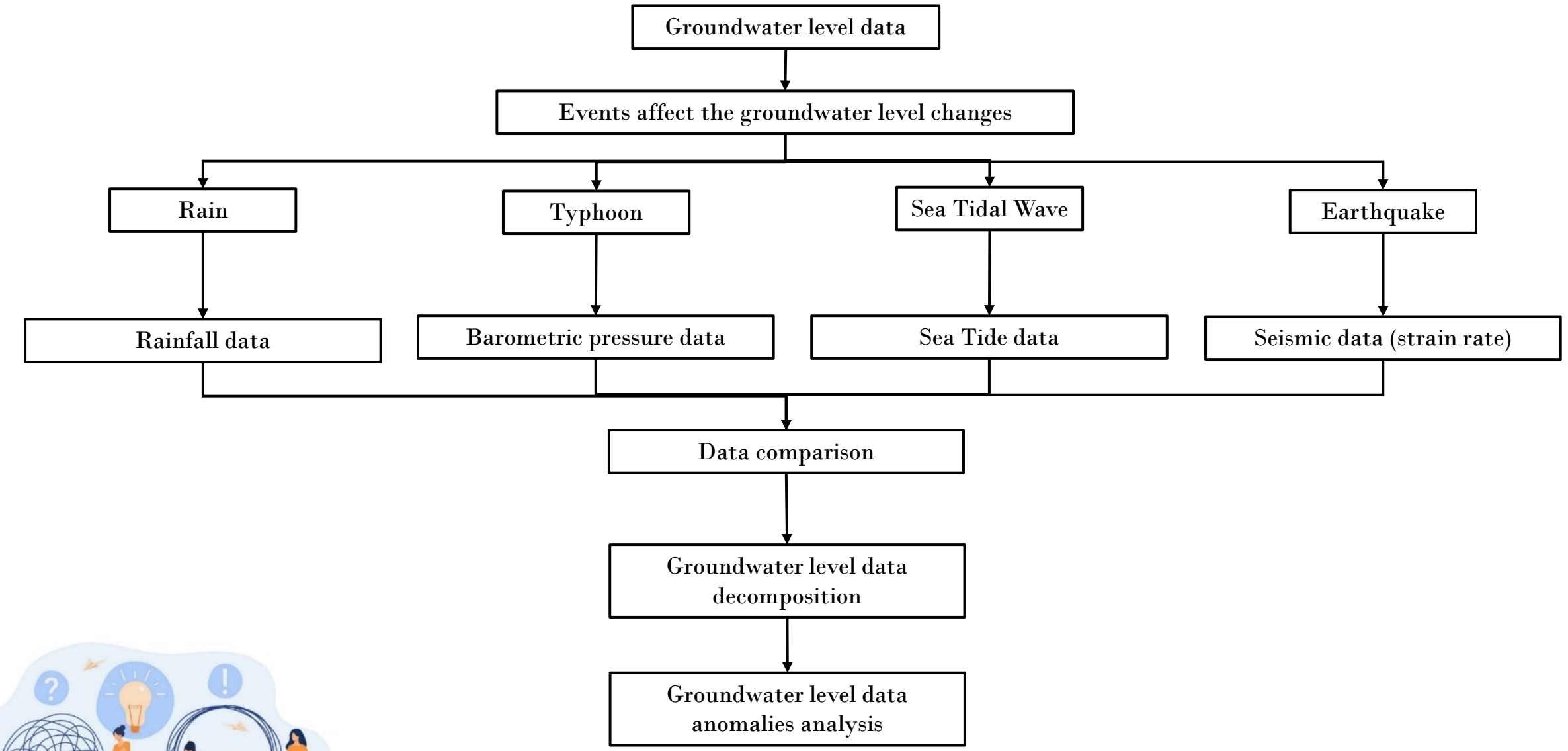
Time history of the groundwater levels in 7 wells located in and around the hypothetical focal zone of the Tokai earthquake **(Matsumoto et al., 2007)**.

Objective

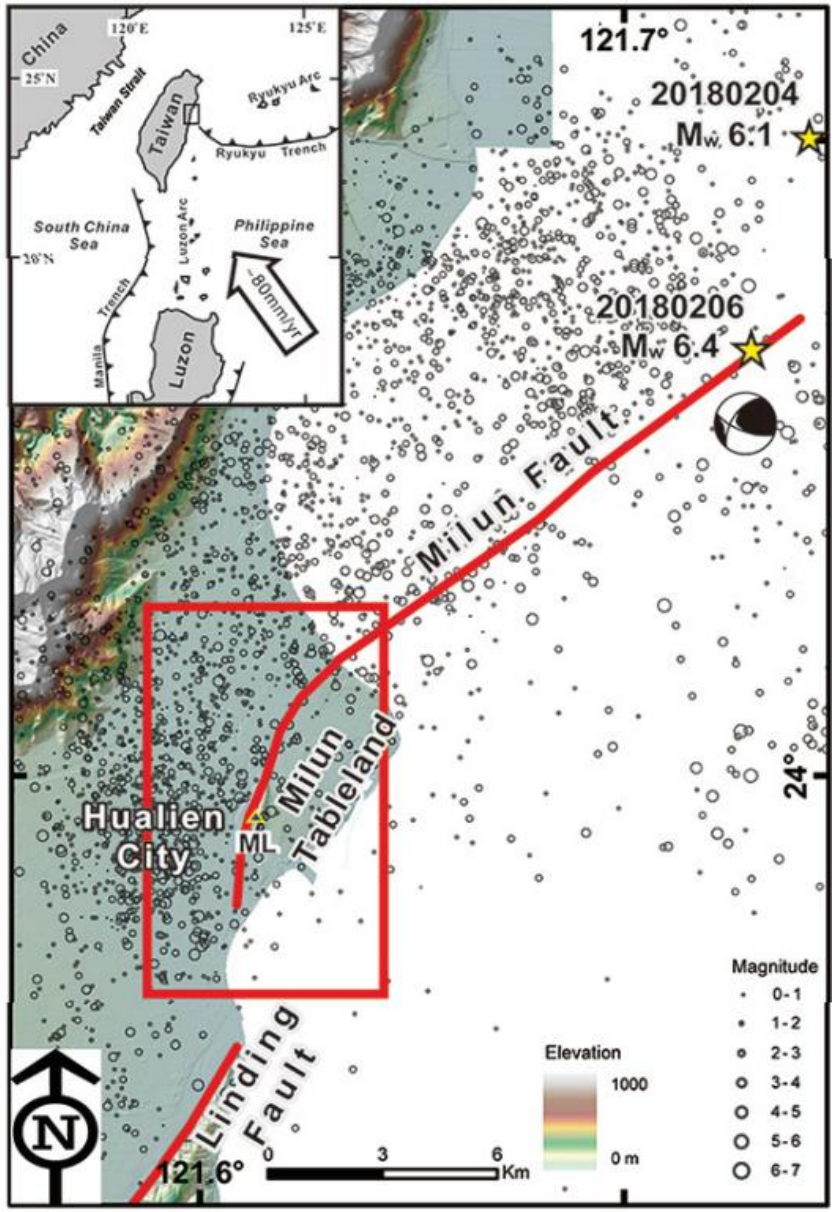
In order to understand the characteristic of the fault-fluid interactions and probability of pre-seismic groundwater level changes, this study objective is to analyze the causes of groundwater level anomaly in Hualien area.

Methodology

Flow Chart:


Groundwater level data
Events affect the groundwater level changes
Rain
Typhoon
Sea Tidal Wave
Earthquake
Rainfall data
Barometric pressure data
Sea Tide data
Seismic data (strain rate)
Data comparison
Groundwater level data decomposition
Groundwater level data anomalies analysis

Study Area



Hualien:

- The area within a 250 km radius of the 2018 Hualien earthquake epicenter has hosted 180 earthquakes of Mw 6.0+, out of which 26 events had a magnitude higher than Mw 7+.
- The Hualien city has experienced several damaging earthquakes due to the complex tectonic setting and ongoing collision between the Philippines Sea Plate and the Eurasian Plate (**Naik et.al., 2022**).

Milun Fault:

- The continuous convergence rate between these plates is approximately ±80 mm per year.
- Hualien experienced numerous earthquakes due to Milun active tectonic setting.

Data Sources

Groundwater Level Data:

- Borehole C
- HWA Station (As a comparison)

Sea Tide Data:

- Sea Tide Gauge

Barometric Pressure Data:

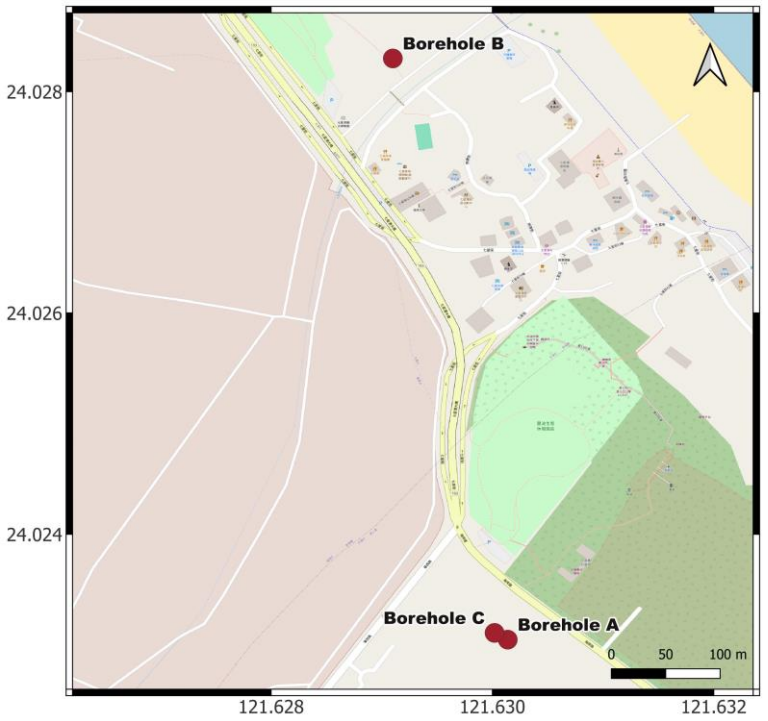
- Borehole C

Seismic Data:

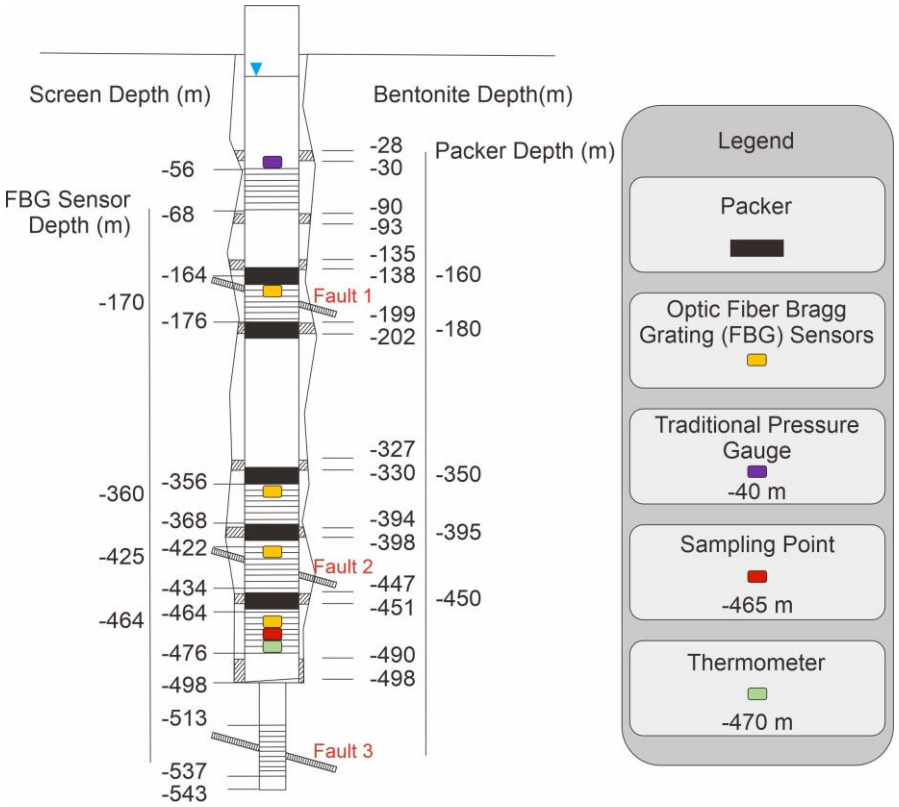
- Borehole A
- Borehole B

Pressure Monitoring Well

The Integrated Observation System of Milun Well



Borehole C



The detail of the system:

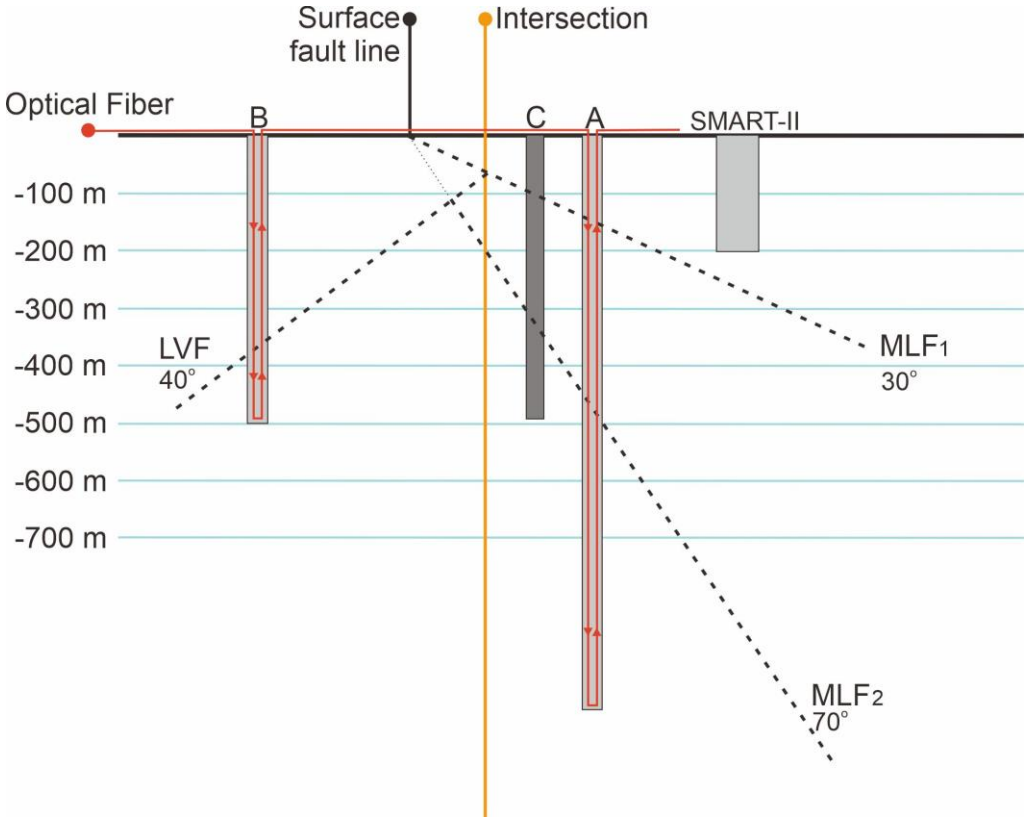
- Screen opening is follow the aquifer system
- The sealed system in each screen
- Water pressure gauge in each screen opening

Water Pressure Sensor:

- -170 m
- -360 m
- -424 m
- -464 m

Seismic Observation Well

Milun fault Drilling and All-inclusive Sensing project (MiDAS)



The detail of the system:

- Located on the northwest edge of Milun Terrace near the coast of Qixingtan
- Optical fiber seismic observation technology combines traditional downhole seismograph with water and gas monitoring in fault zone.

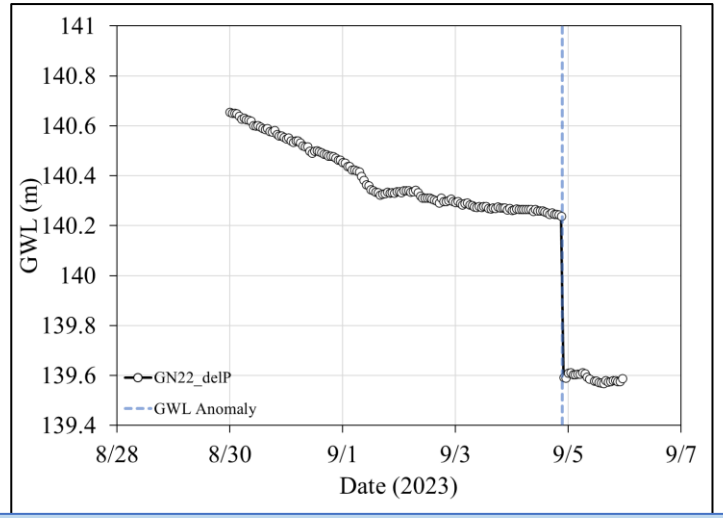
Data Analysis and Discussion

Groundwater Level Anomalies in Different Depth

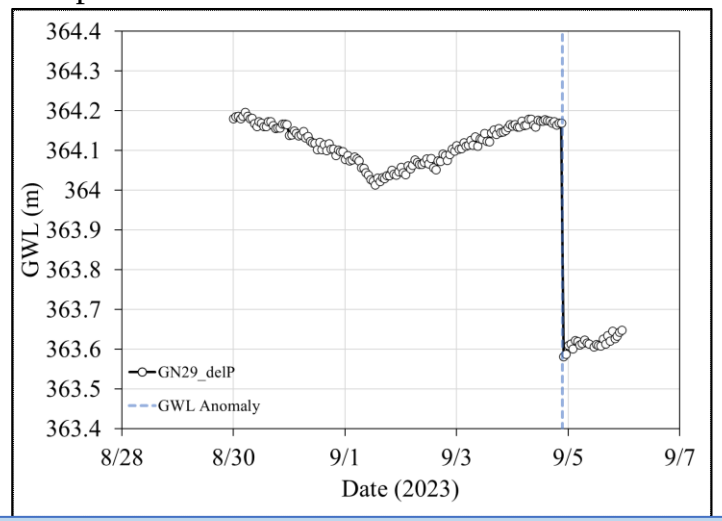
Time: September 4th 2023 (Recorded even in the hourly data)

Milun Integrated Observation System (Borehole C)

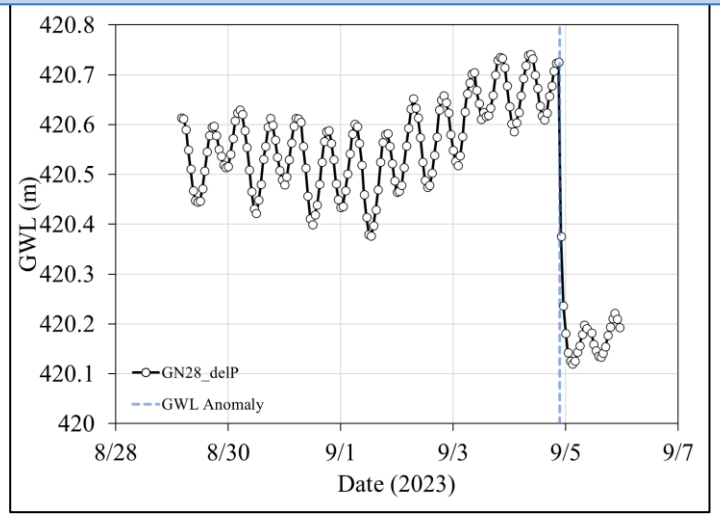
Depth :170 m

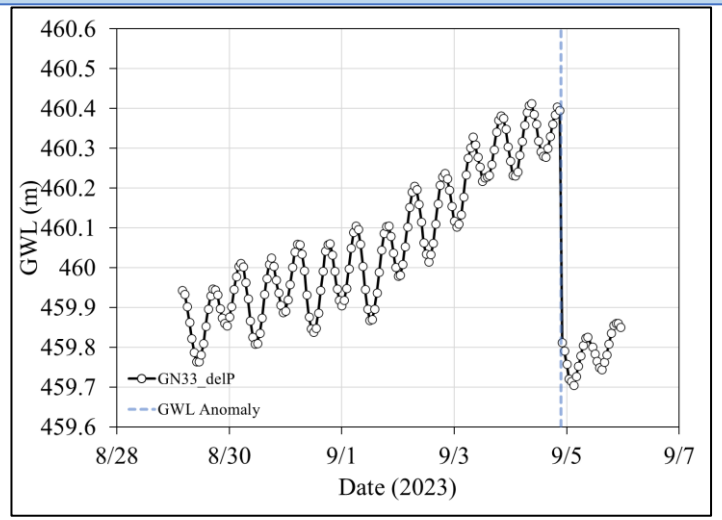


Depth :360 m

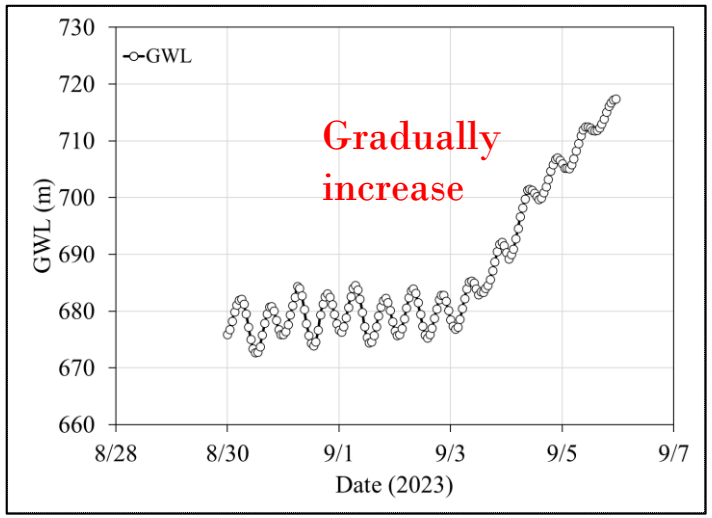


What is the cause(s) of groundwater level has step-like changes?





Hualien Well (HWA) (as comparison)



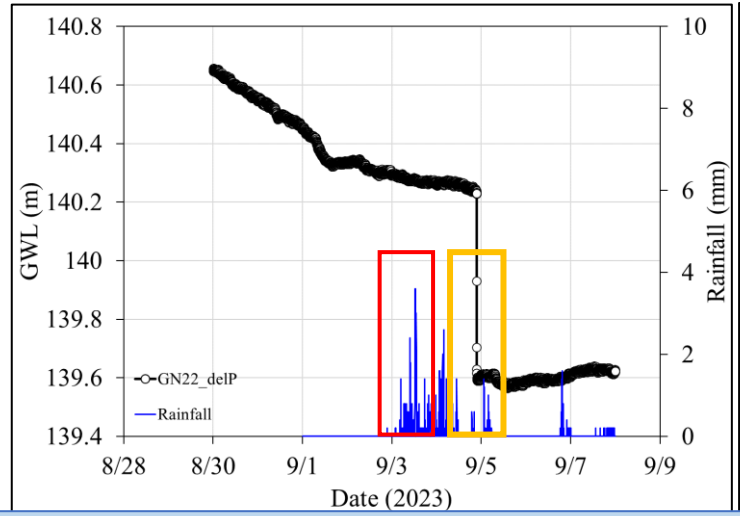
What is the cause(s) of groundwater level has gradually increase?

Events Related to the Groundwater Anomalies

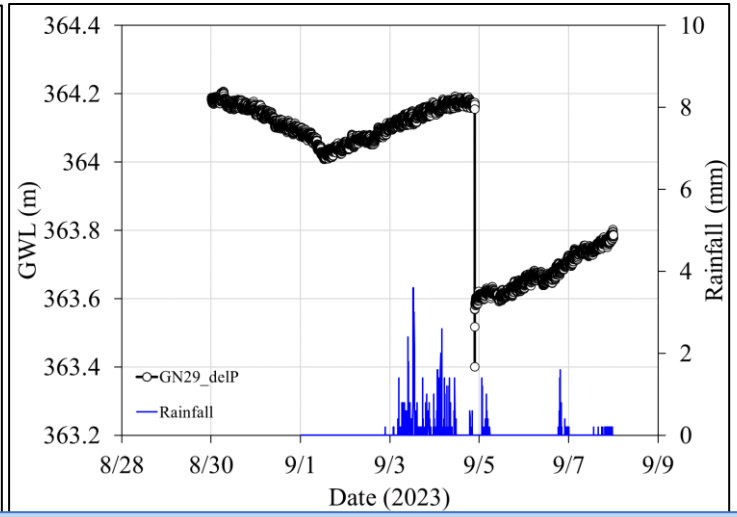
Rainfall

Milun Integrated Observation System (borehole C)

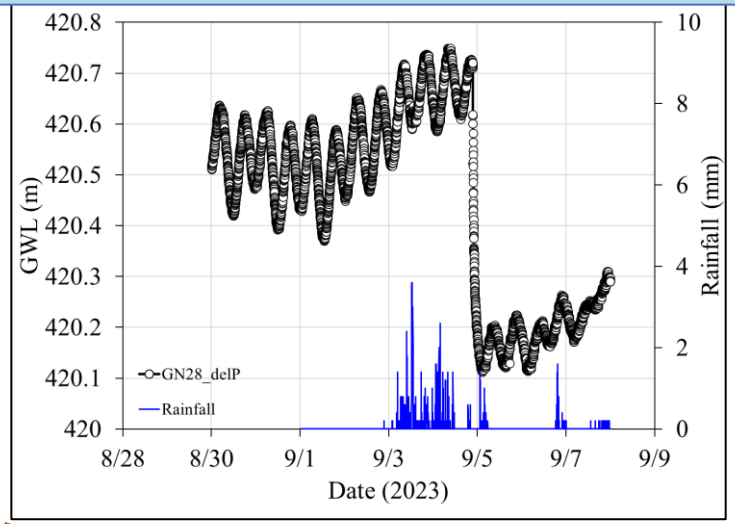
Depth :170 m

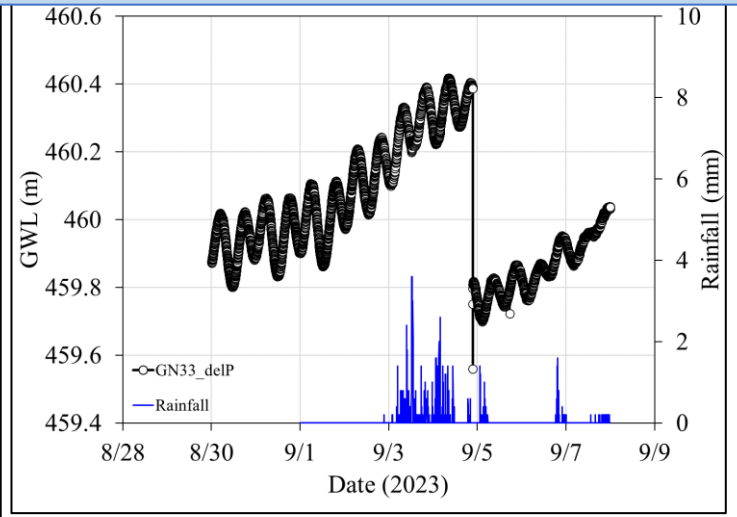


Depth :360 m

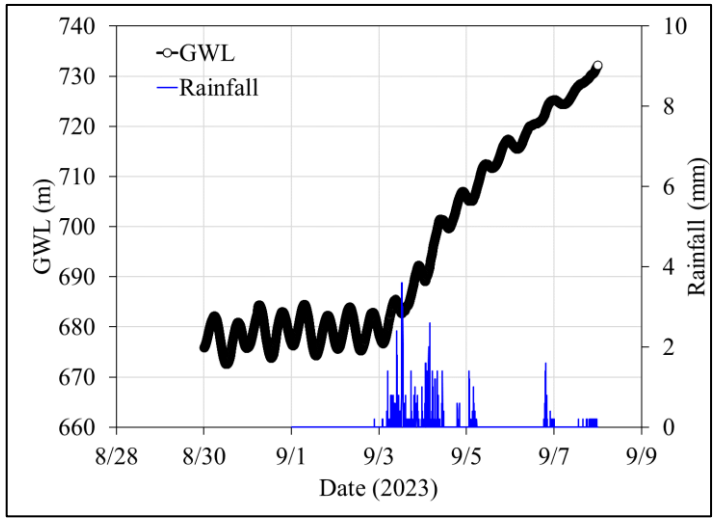


Inconsistent response due to rainfall (recharge).





Hualien Well (HWA)

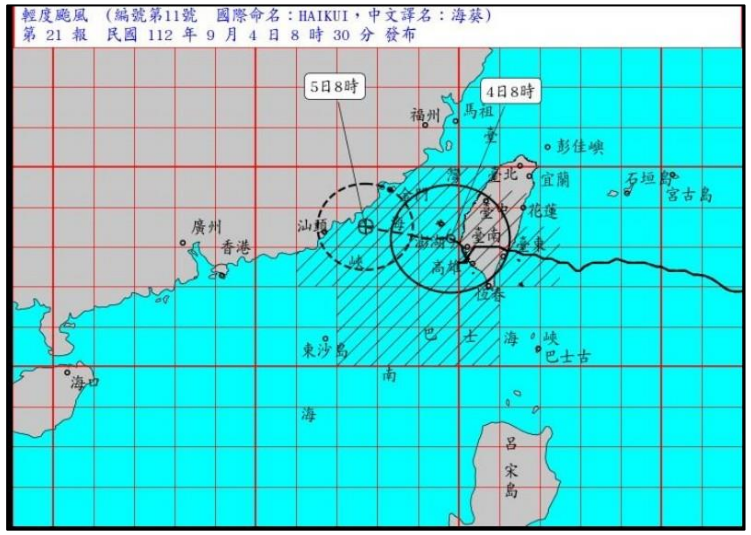


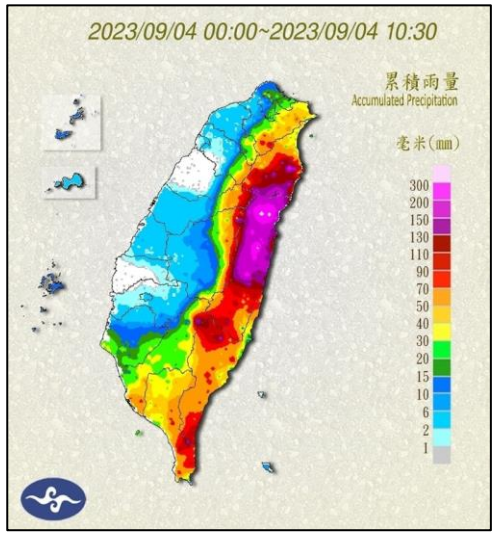
Rainfall effect?

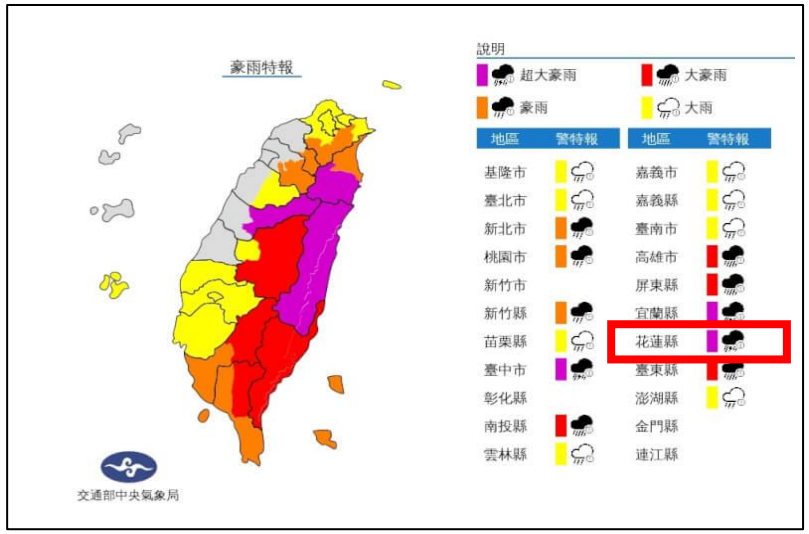
Events Related to the Groundwater Anomalies

Typhoon (Barometric Pressure)

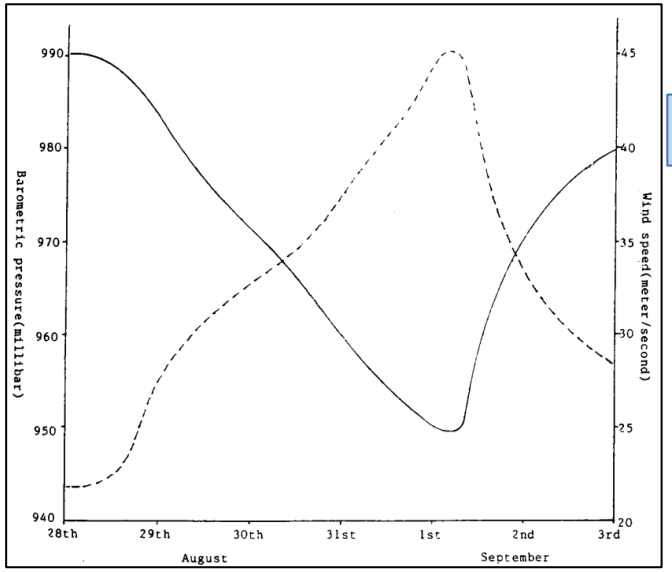
HAKUI Duration:







Barometric pressure decrease due to the Typhoon

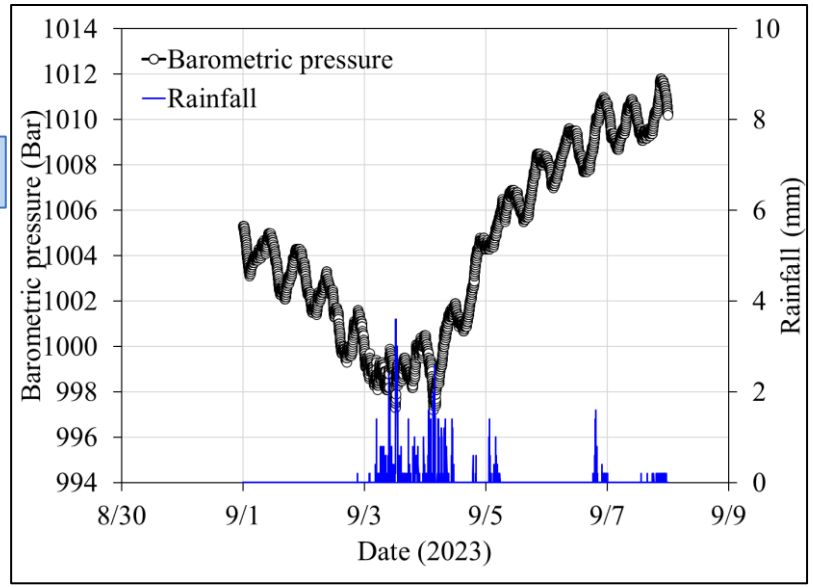


How it's affect the groundwater level?

——— : Barometric pressure

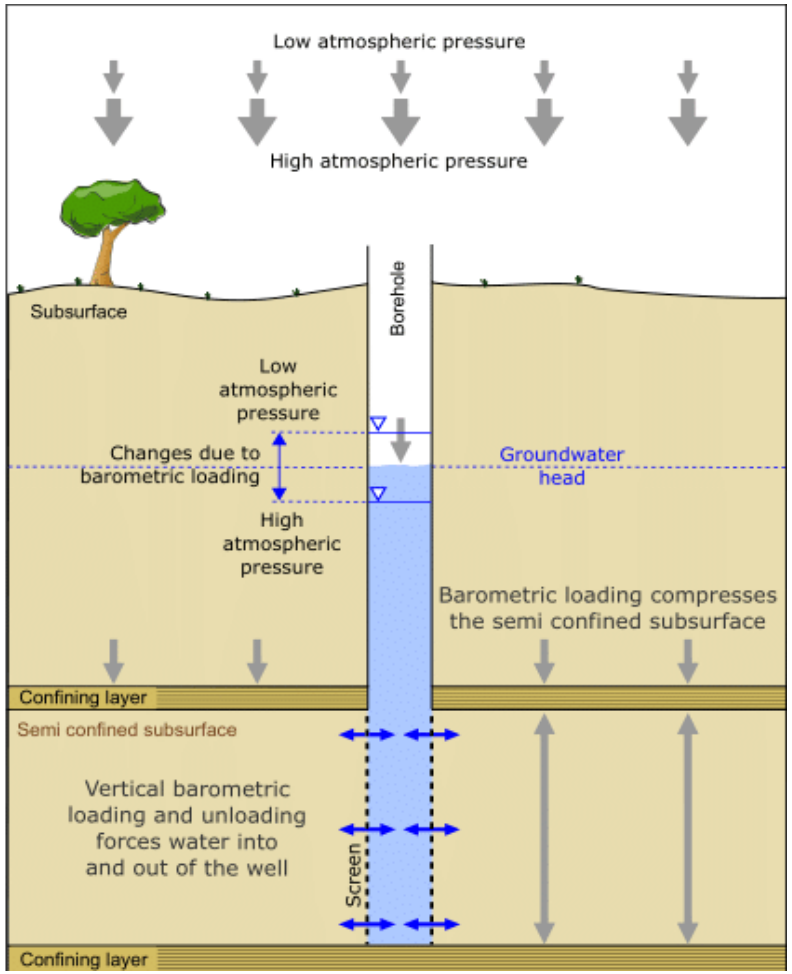
..... : Wind speed

(Jin-Lai & Xun-Ren , 1986)



Events Related to the Groundwater Anomalies

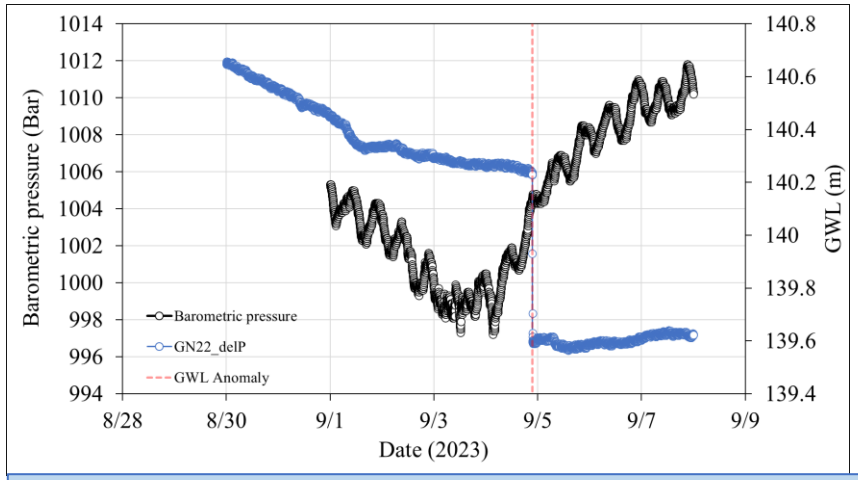
Barometric pressure affect groundwater level



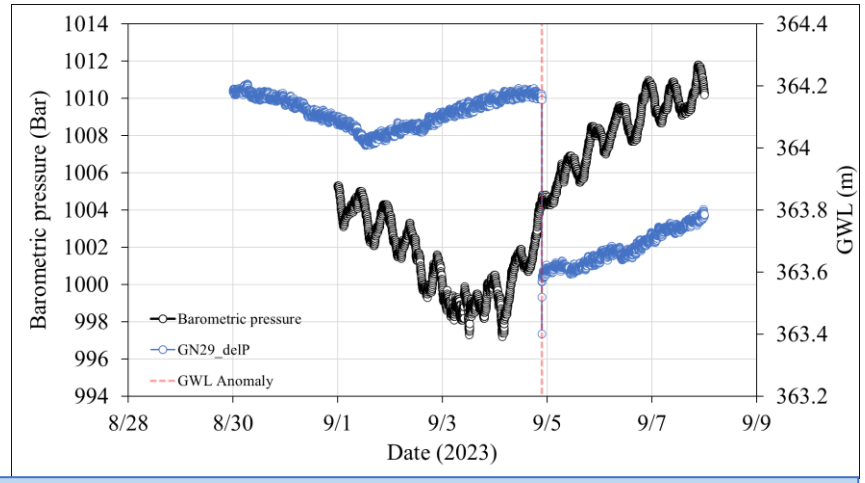
Barometric pressure decrease

Groundwater level increase

Depth :170 m

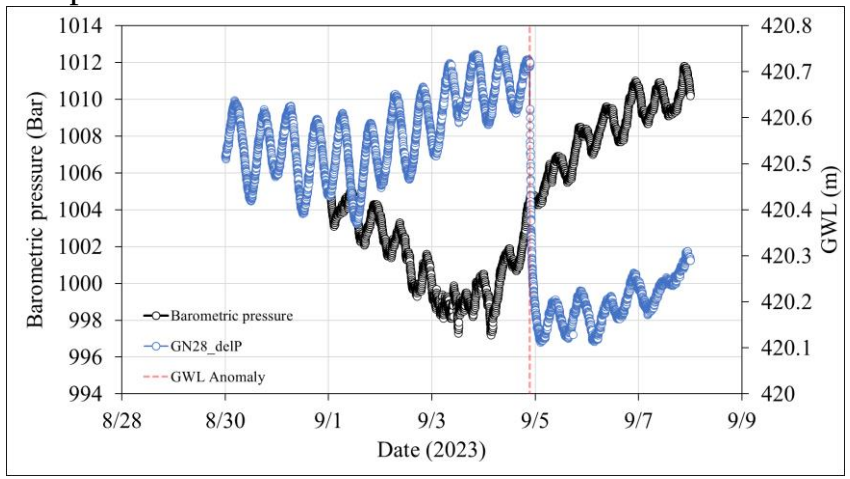


Depth :360 m

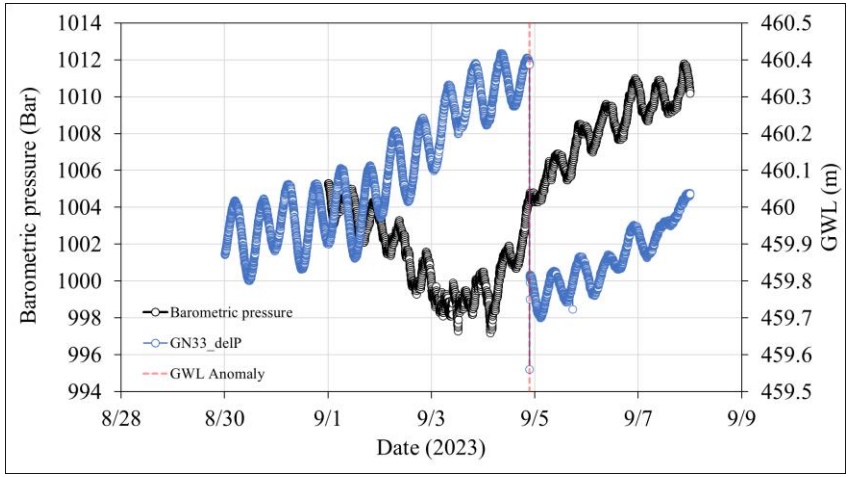


Milun well has sealed system. Do barometric pressure affect the groundwater level fluctuation?

Depth :424 m

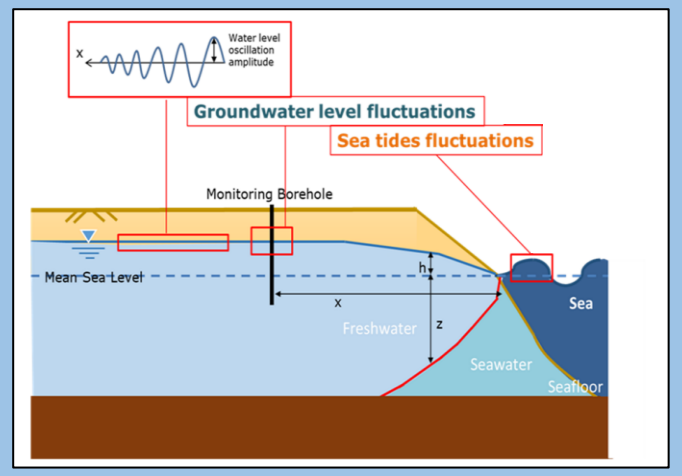


Depth :464 m



Events Related to the Groundwater Anomalies

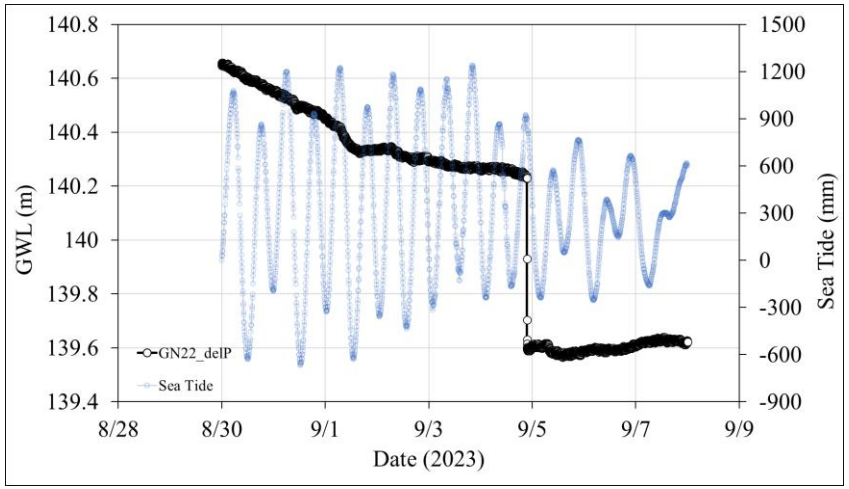
Sea Tide



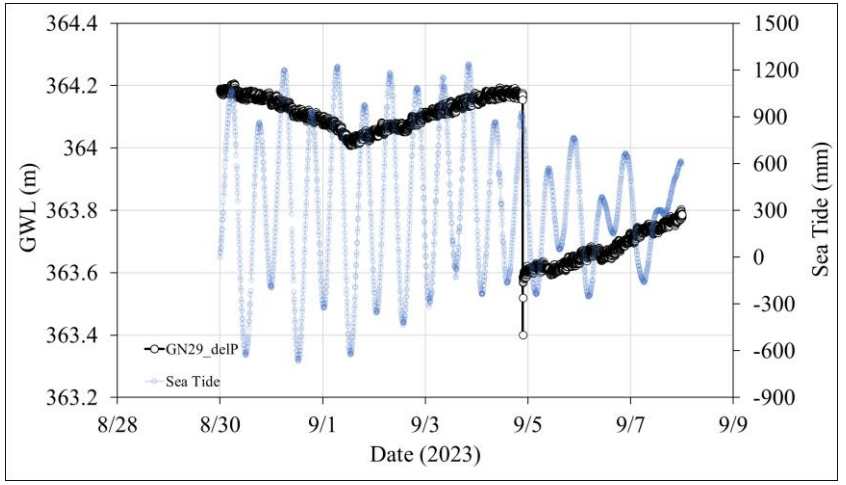
Sea tide increase

Groundwater level increase

Depth :170 m

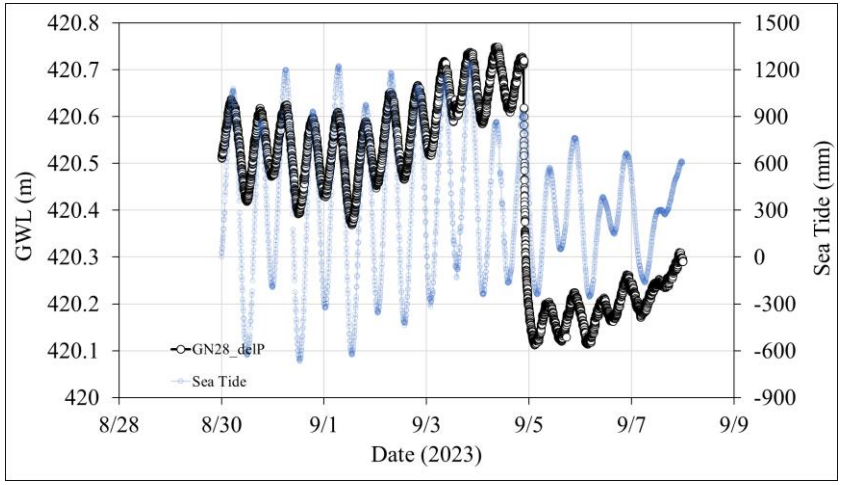


Depth :360 m

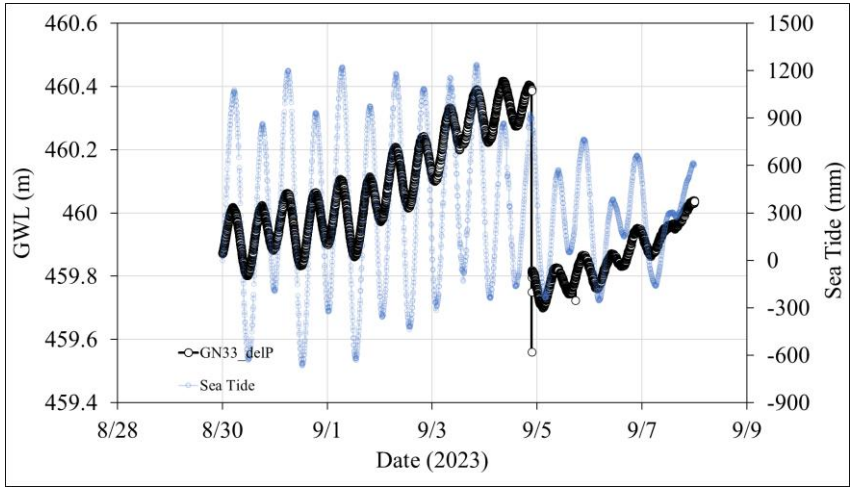


Time shifting and signal decomposition to get clear groundwater level data.

Depth :424 m

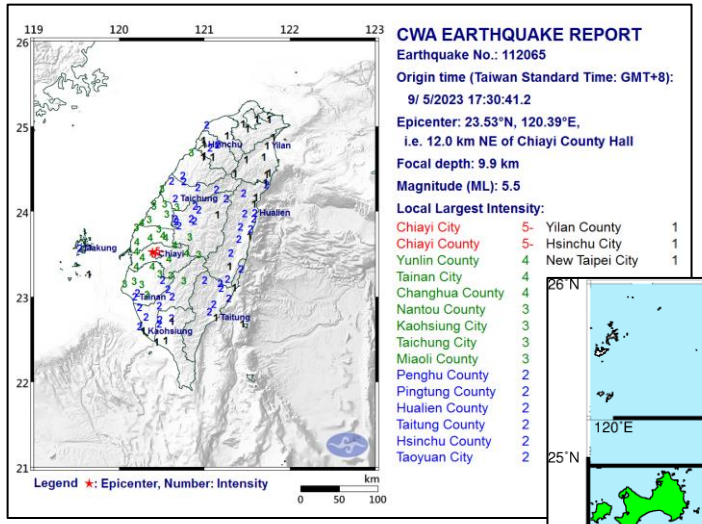


Depth :464 m

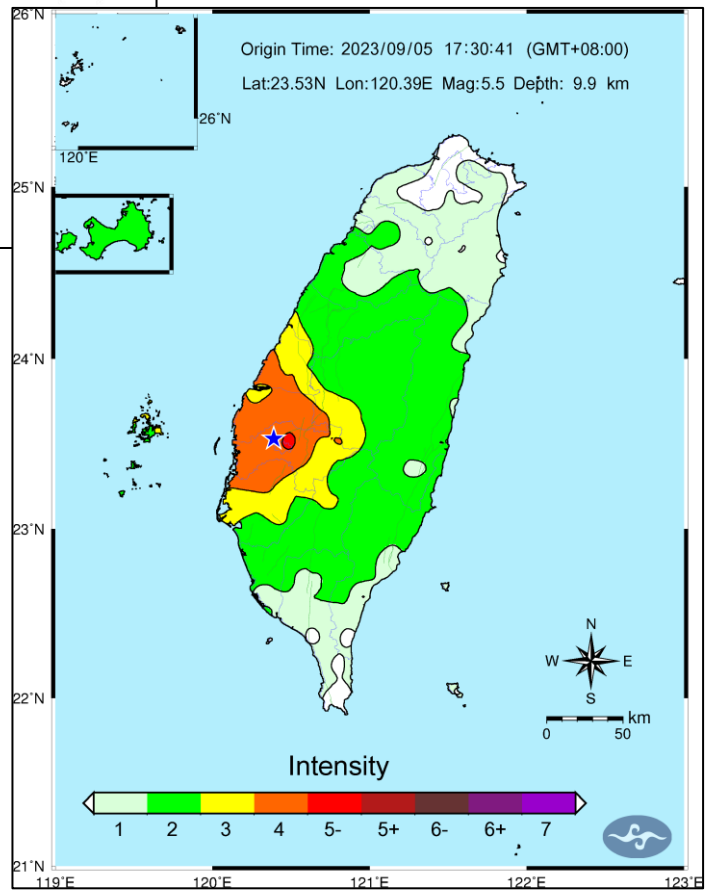


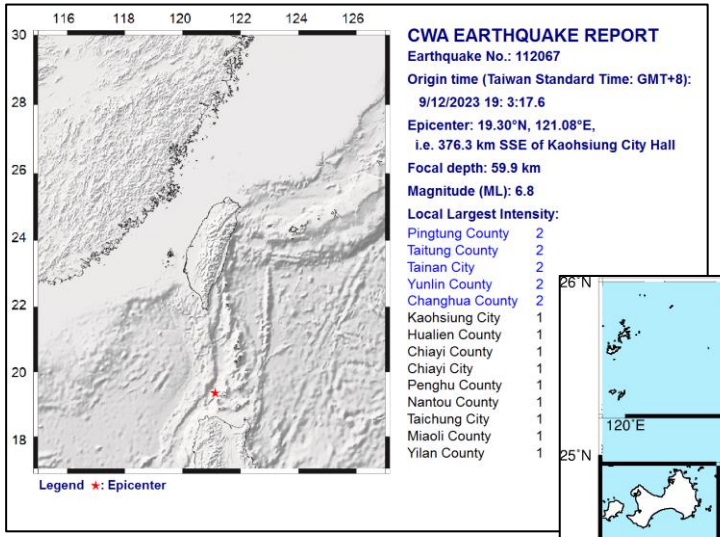
Events Related to the Groundwater Anomalies

Earthquake Events

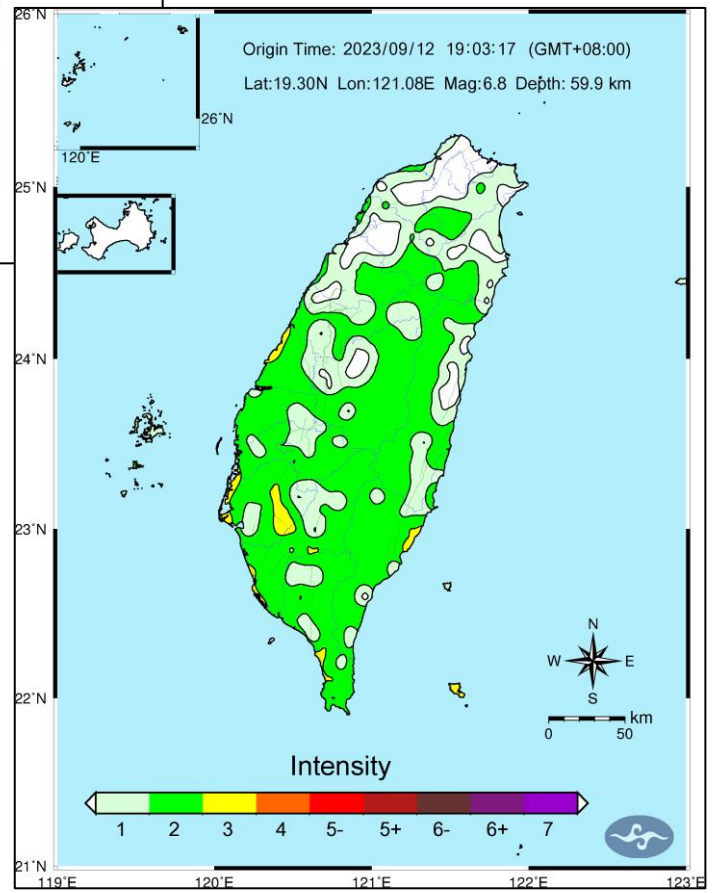


2023/09/05 (17.30)



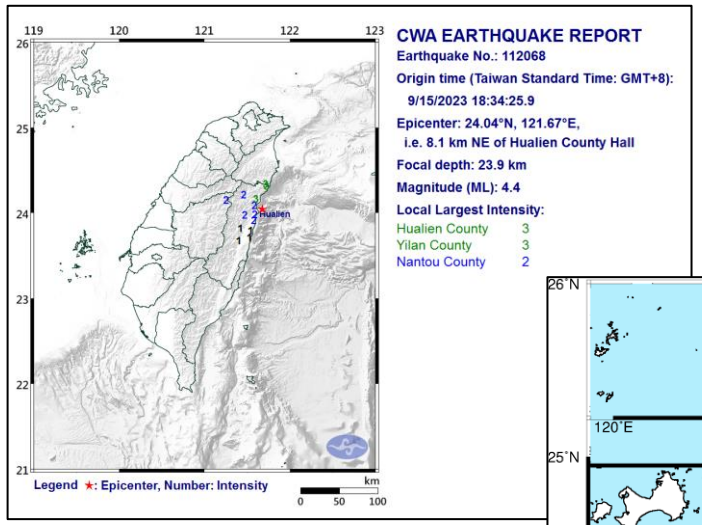


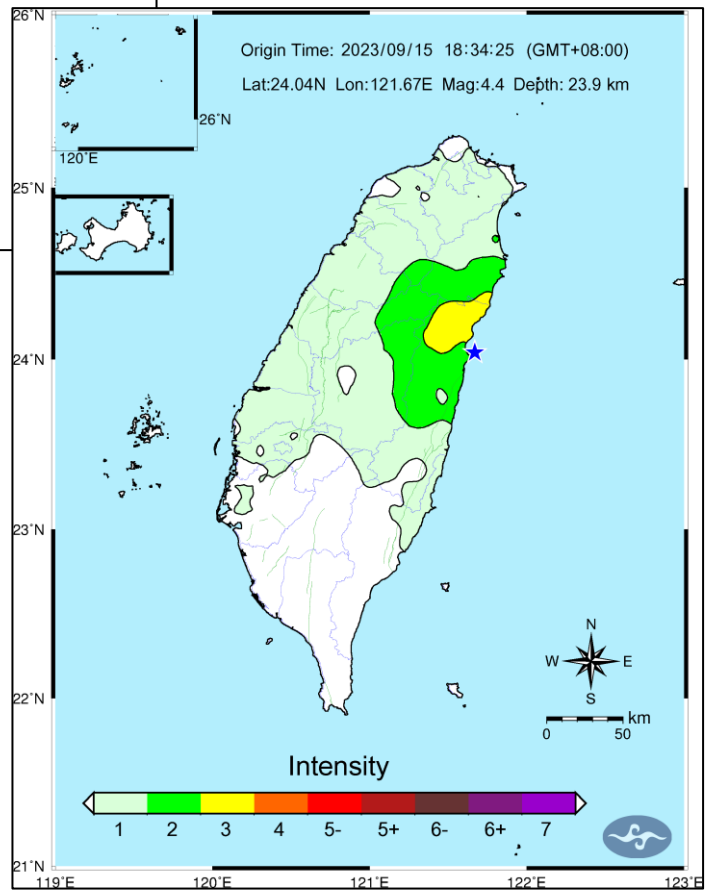
2023/09/12 (19.03)



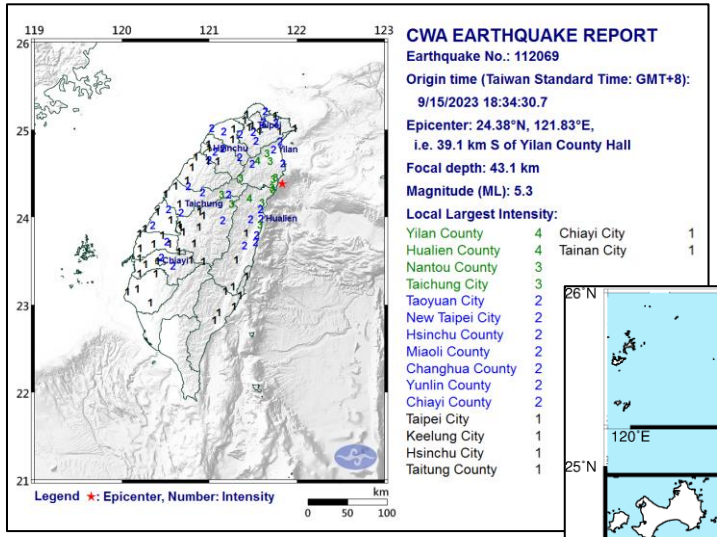
Events Related to the Groundwater Anomalies

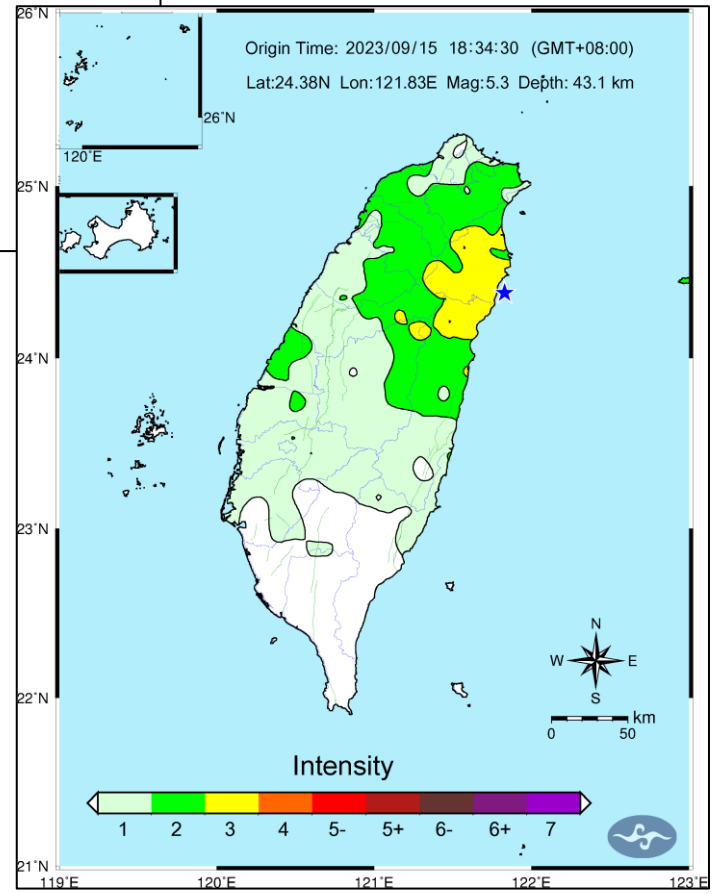
Earthquake Events





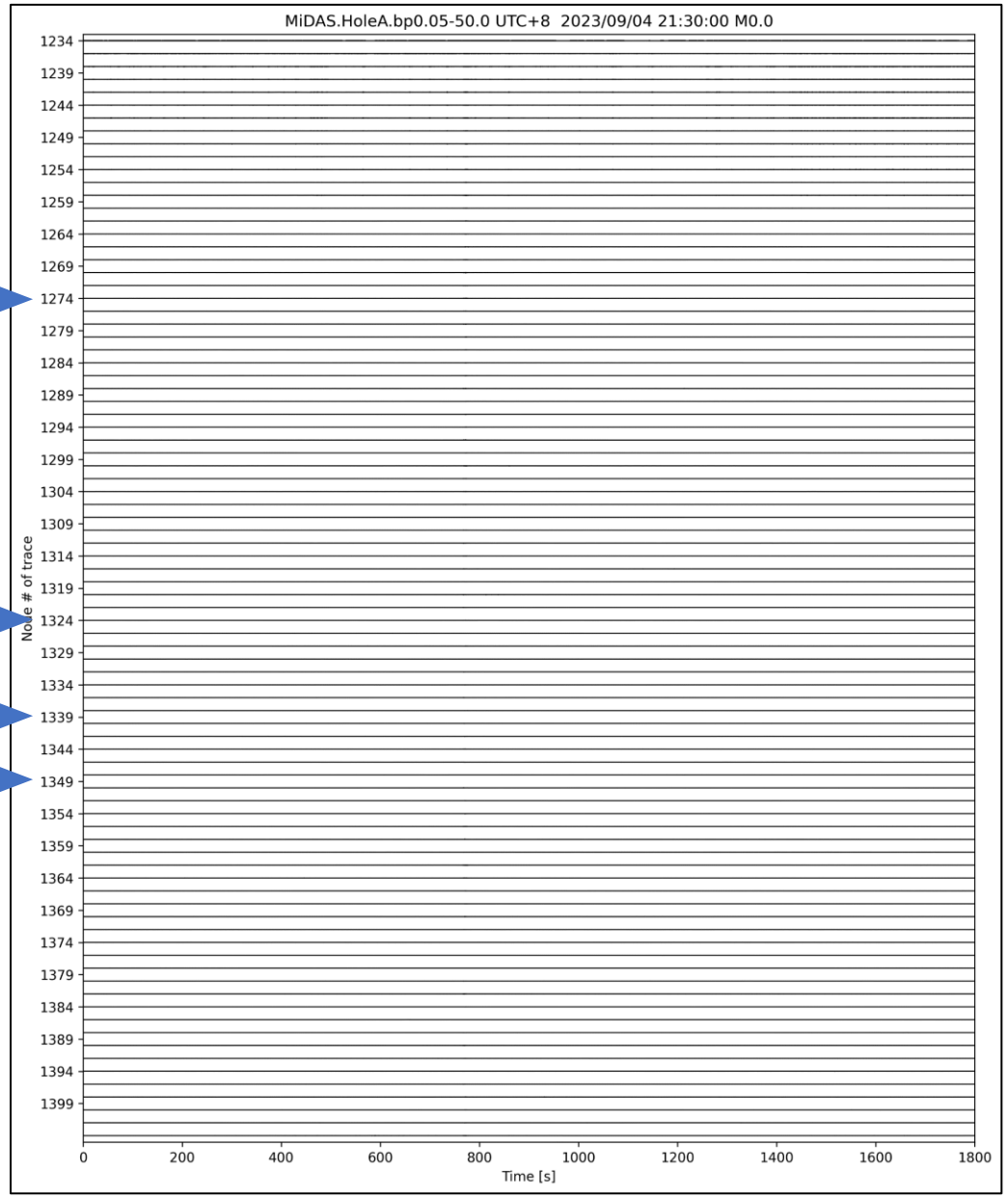
2023/09/15 (18.34)





2023/09/15 (18.34)

Seismic Data in Each Depth (2023/09/04 (21.30))



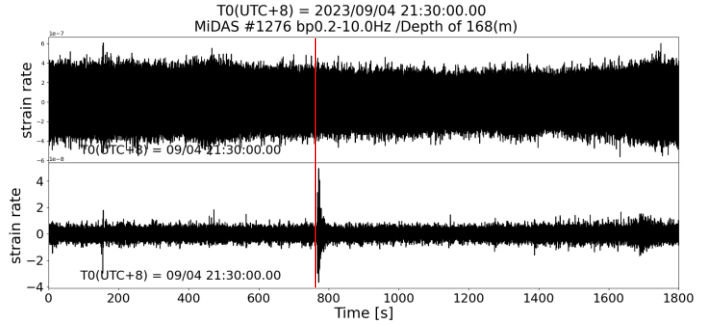
170 m → Raw data → Filter Bandpass 0.2-10Hz

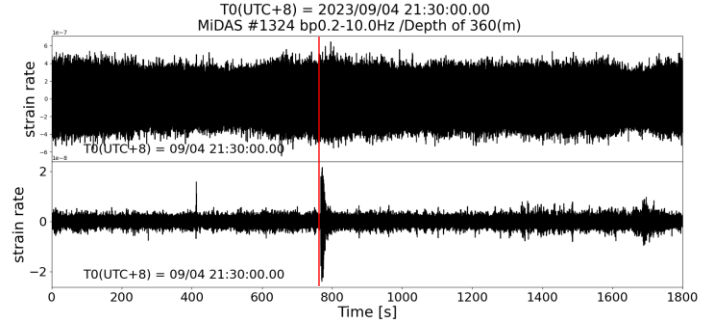
360 m → Raw data → Filter Bandpass 0.2-10Hz

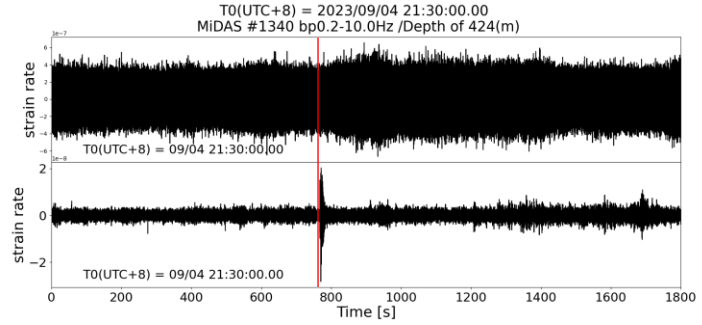
424 m → Raw data → Filter Bandpass 0.2-10Hz

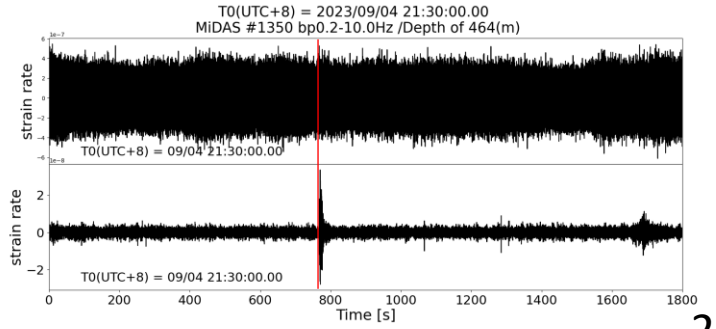
464 m → Raw data → Filter Bandpass 0.2-10Hz

High strain rate time: 21:42:45

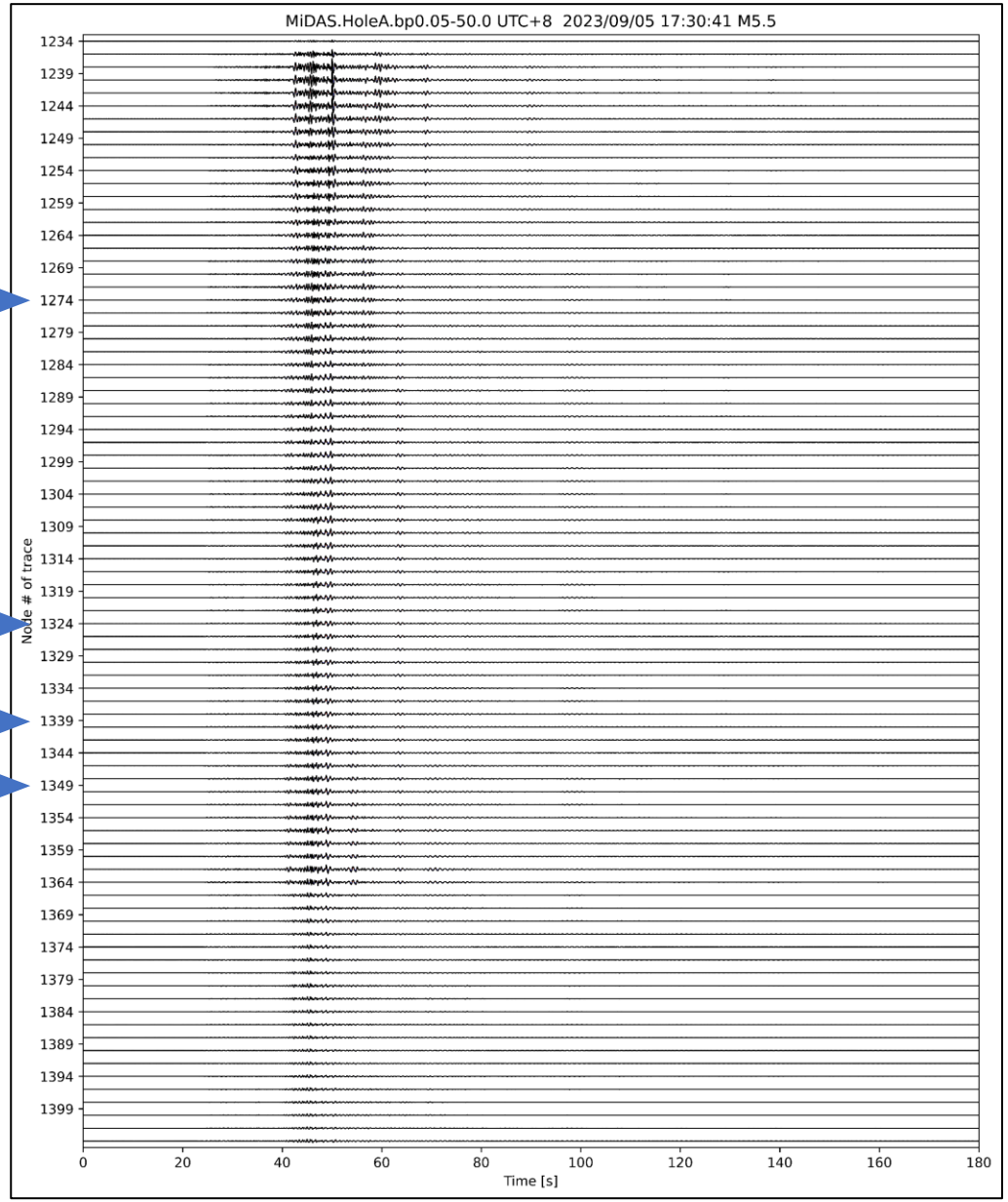




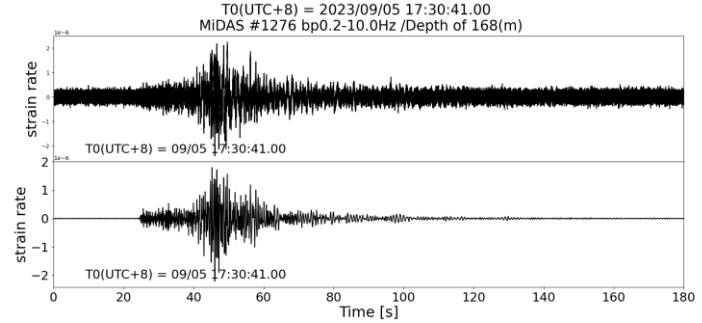




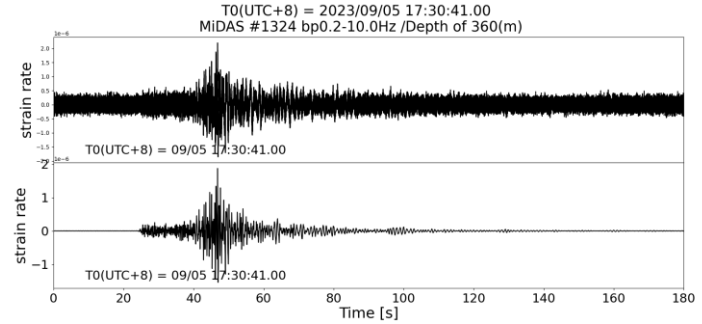
Seismic Data in Each Depth (2023/09/05 (17.30))



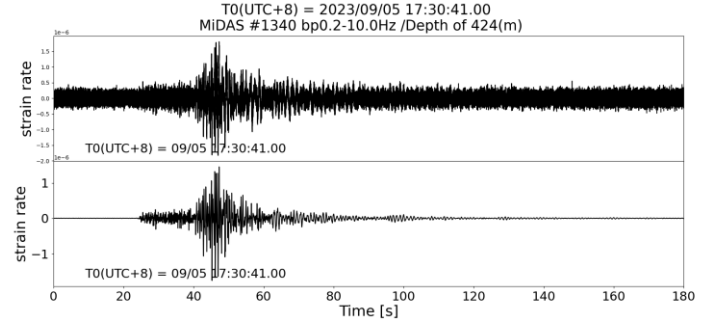
170 m → Raw data → Filter Bandpass 0.2-10Hz



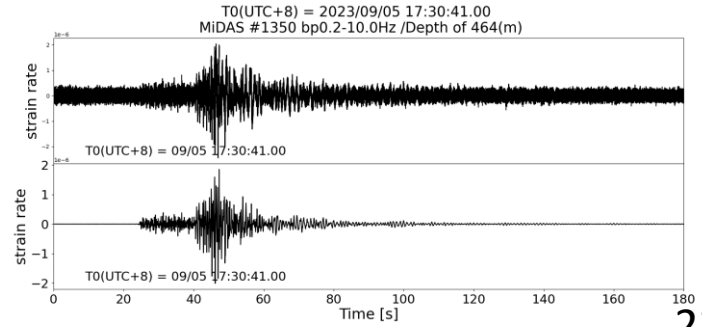
360 m → Raw data → Filter Bandpass 0.2-10Hz



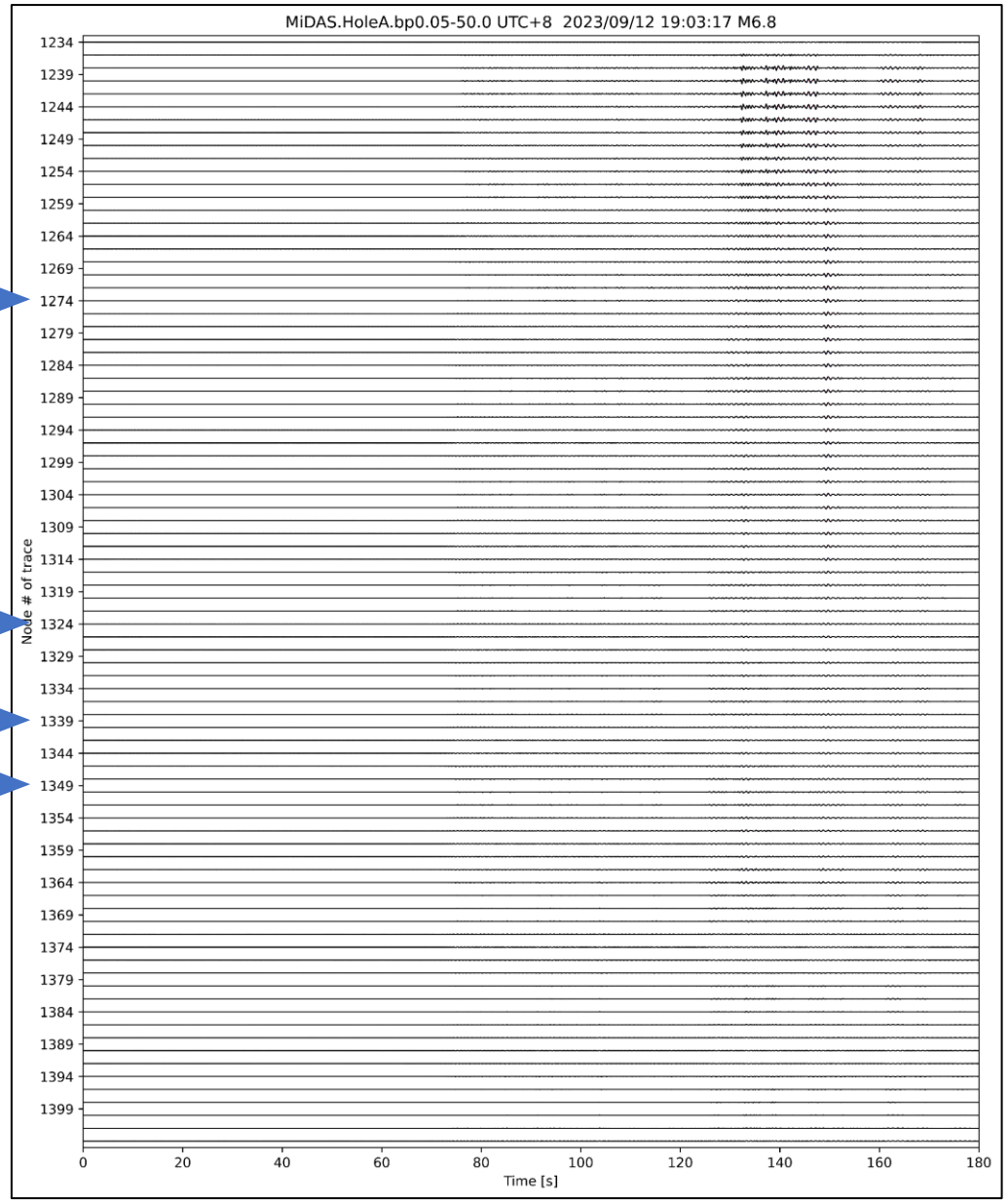
424 m → Raw data → Filter Bandpass 0.2-10Hz



464 m → Raw data → Filter Bandpass 0.2-10Hz



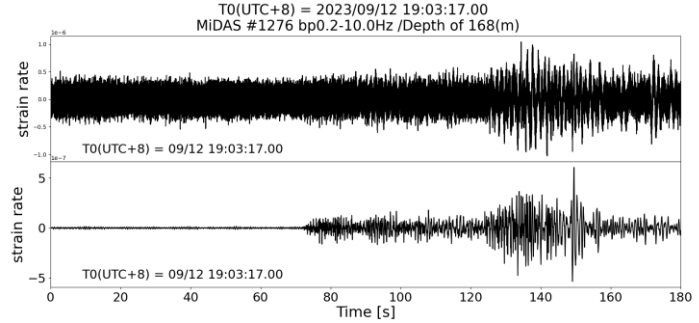
Seismic Data in Each Depth (2023/09/12 (19.03))



170 m

Raw data

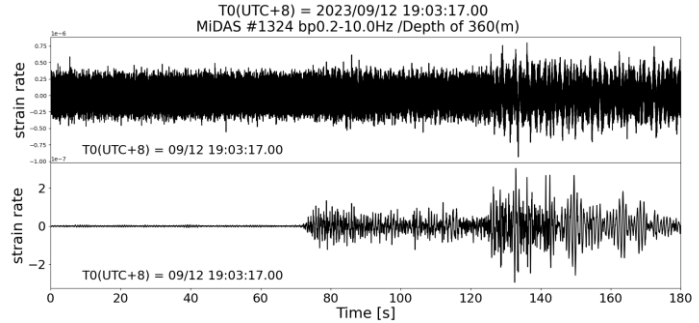
Filter
Bandpass 0.2-10Hz



360 m

Raw data

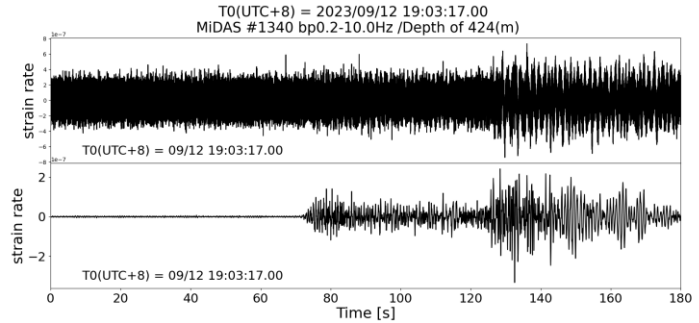
Filter
Bandpass 0.2-10Hz



424 m

Raw data

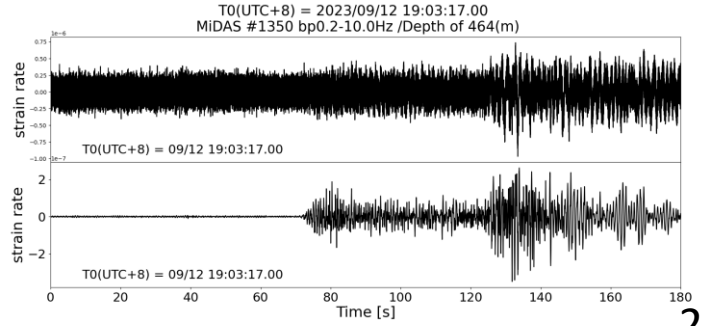
Filter
Bandpass 0.2-10Hz



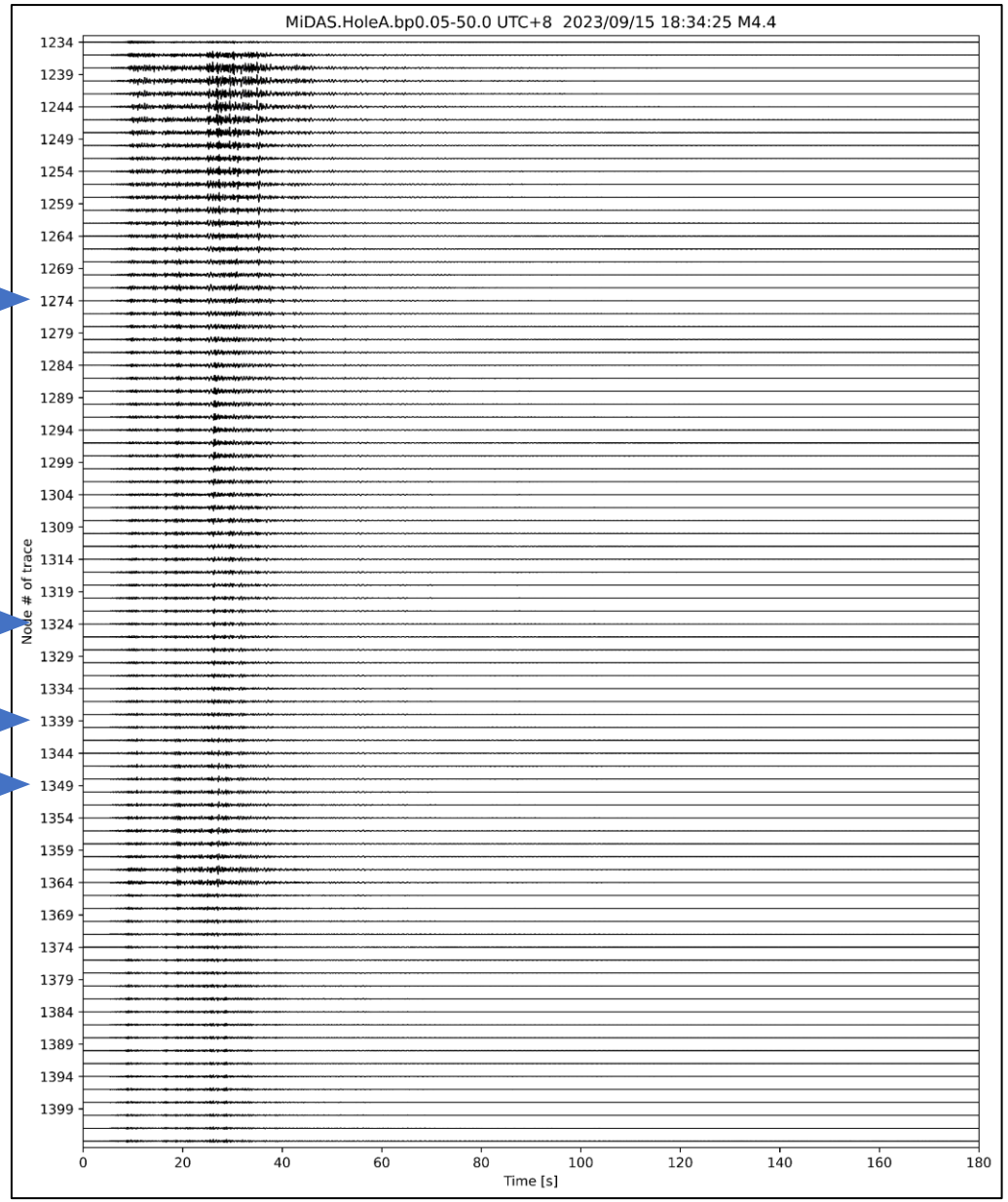
464 m

Raw data

Filter
Bandpass 0.2-10Hz



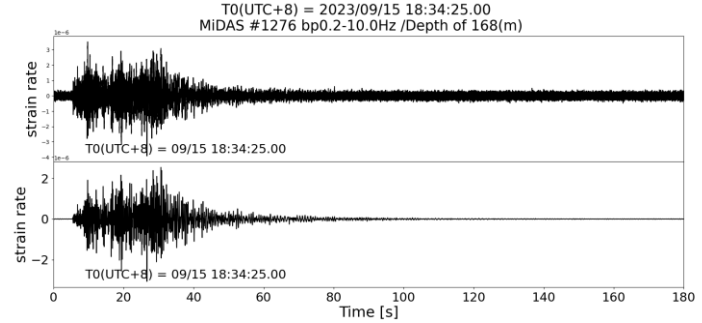
Seismic Data in Each Depth (2023/09/15 (18.34))



170 m

Raw data

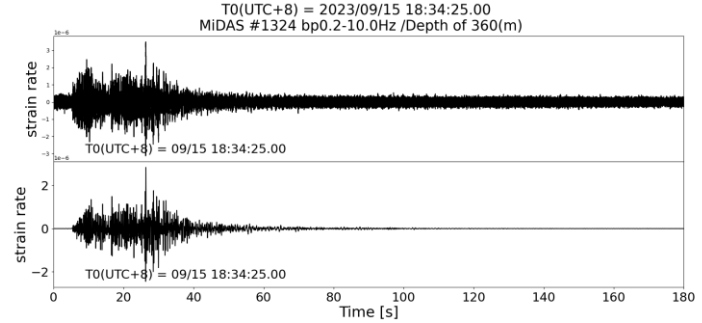
Filter
Bandpass 0.2-10Hz



360 m

Raw data

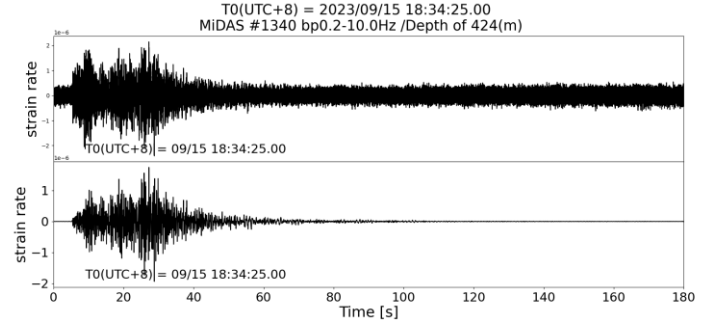
Filter
Bandpass 0.2-10Hz



424 m

Raw data

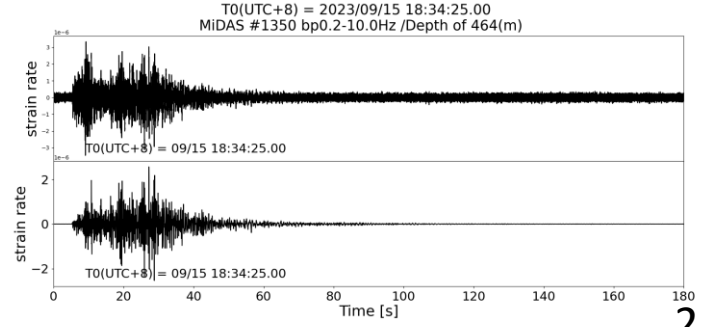
Filter
Bandpass 0.2-10Hz



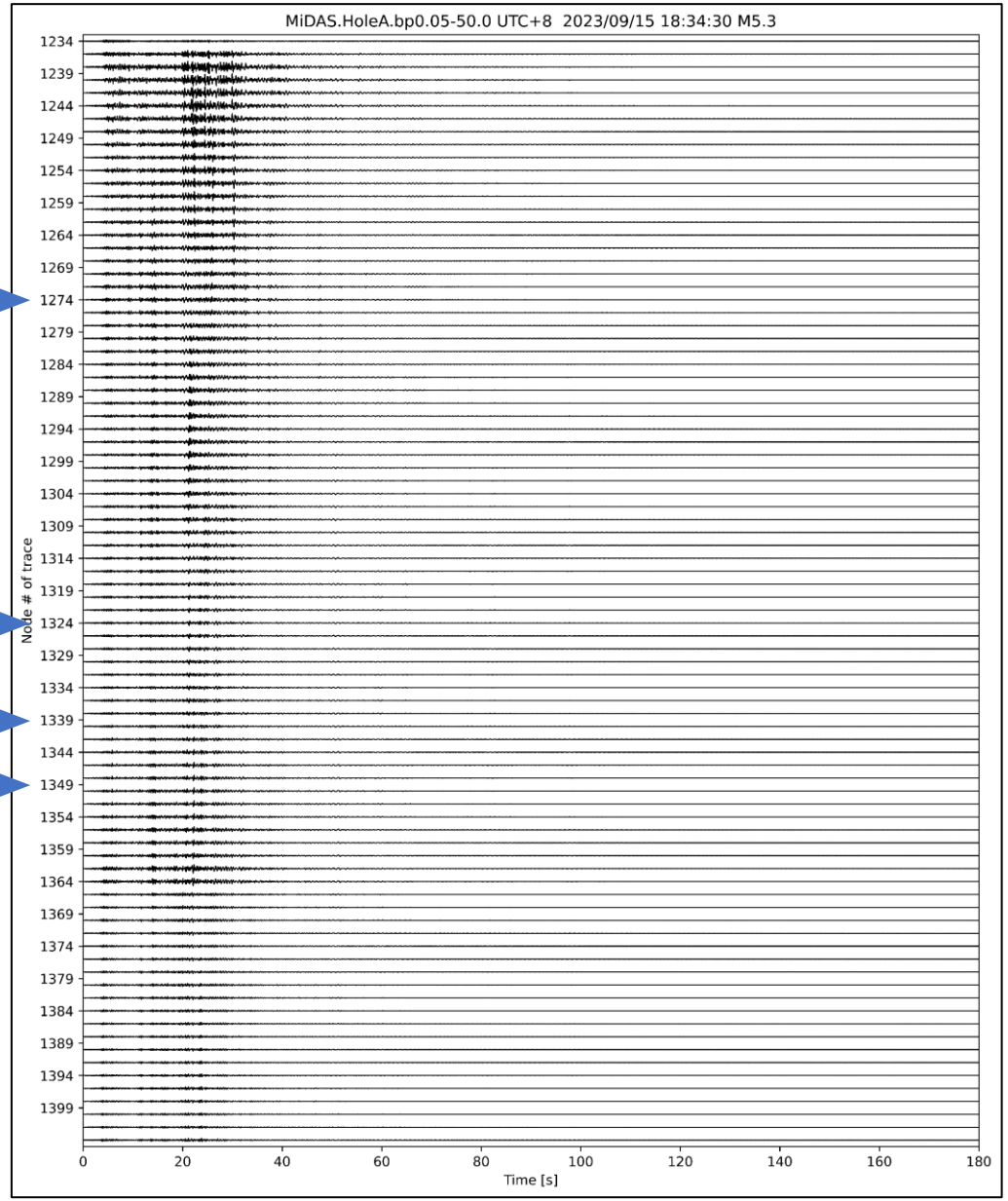
464 m

Raw data

Filter
Bandpass 0.2-10Hz



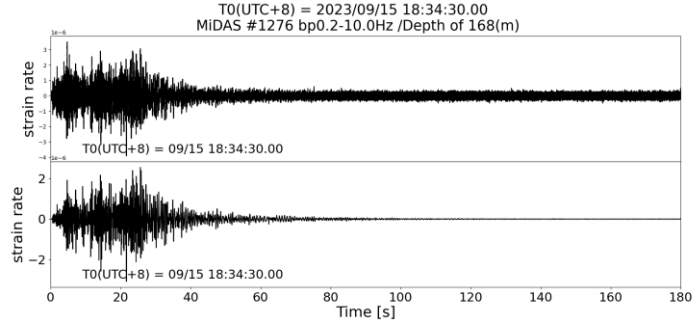
Seismic Data in Each Depth (2023/09/15 (18.34))



170 m

Raw data

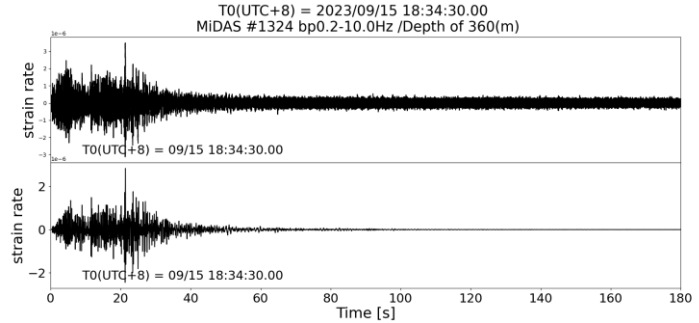
Filter
Bandpass 0.2-10Hz



360 m

Raw data

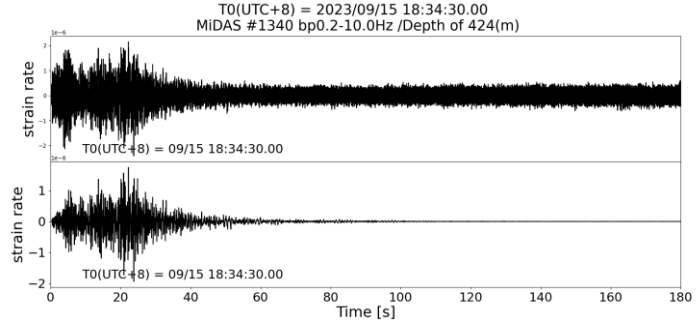
Filter
Bandpass 0.2-10Hz



424 m

Raw data

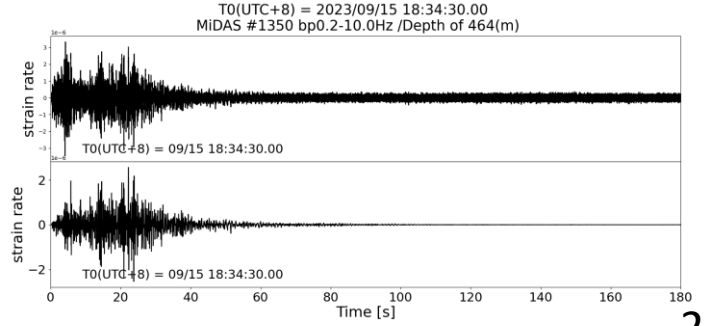
Filter
Bandpass 0.2-10Hz



464 m

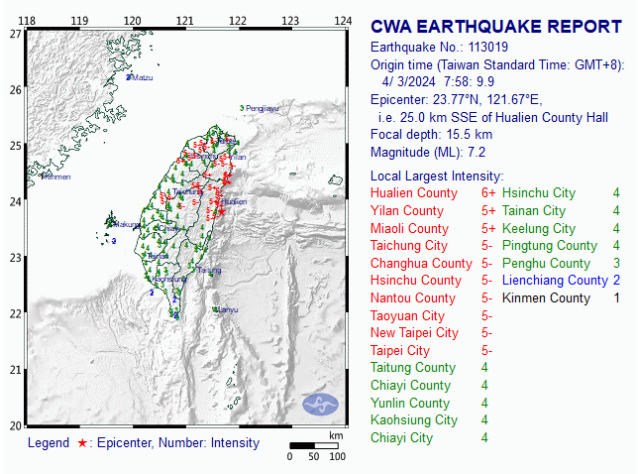
Raw data

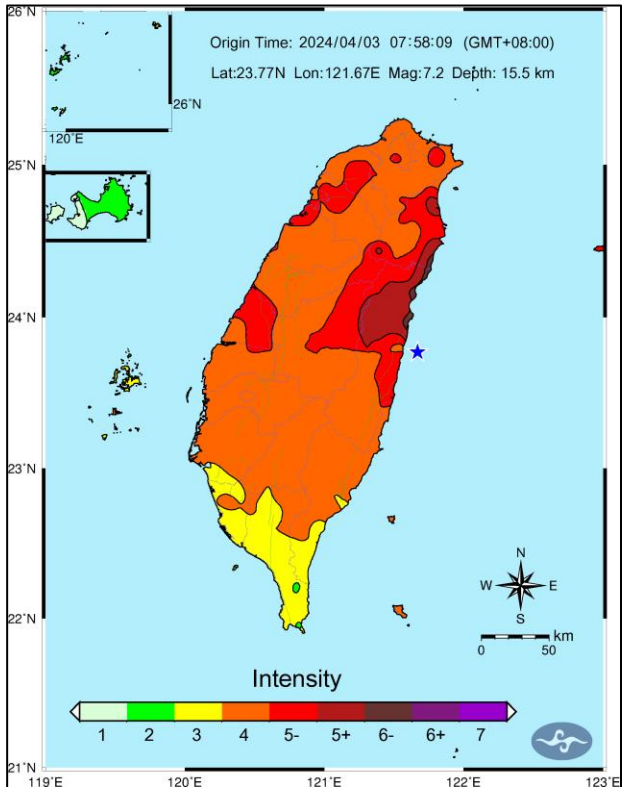
Filter
Bandpass 0.2-10Hz



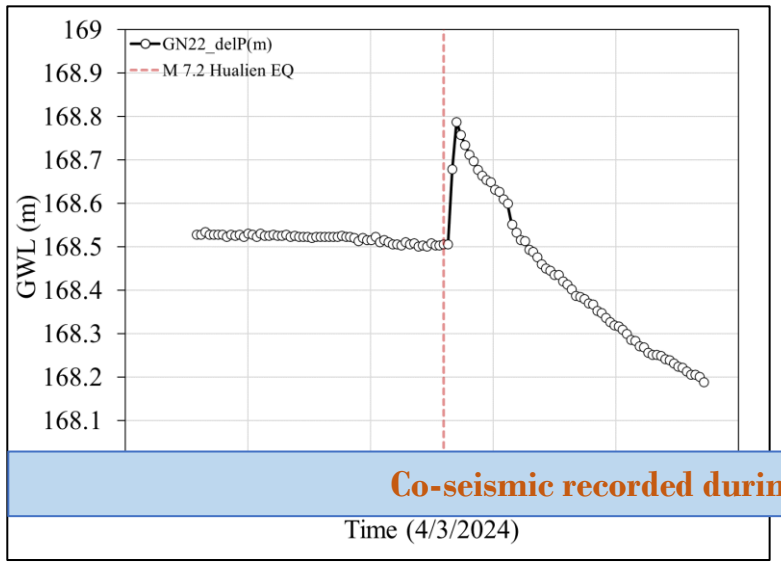
Events Related to the Groundwater Anomalies

Hualien Earthquake (April 3rd 2024)

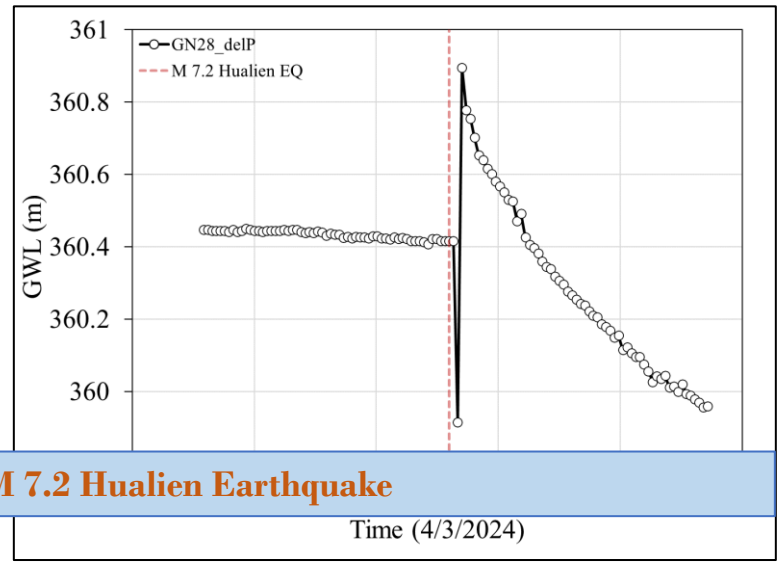




Depth :170 m

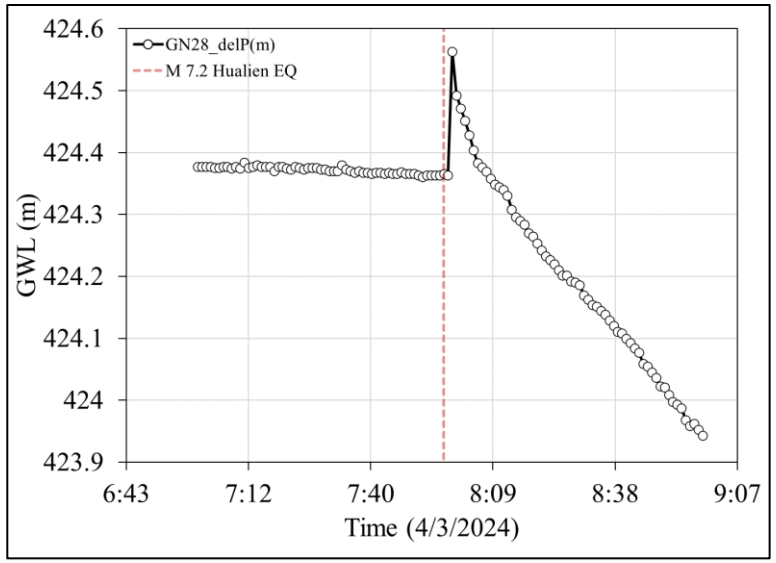


Depth :360 m

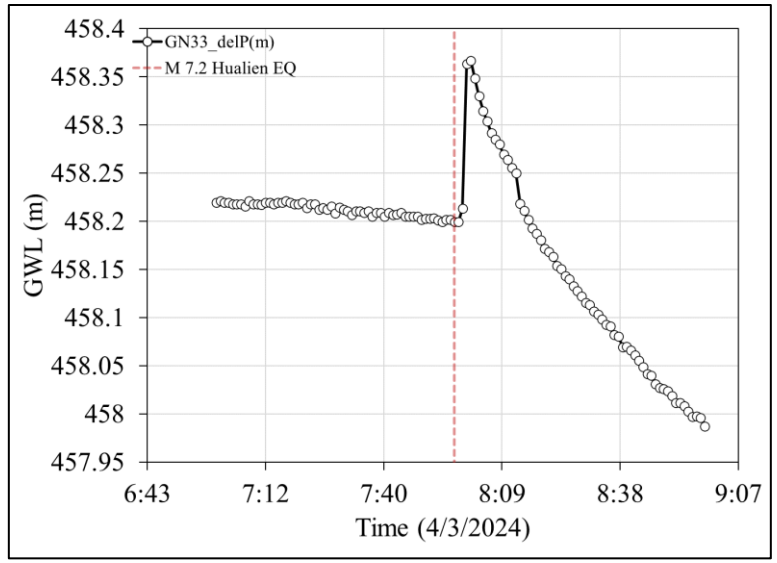


Co-seismic recorded during M 7.2 Hualien Earthquake

Depth :424 m



Depth :464 m



No Conclusion

Are the step changes in groundwater level a signal of earthquake precursor or relative to fault activity?

Future Works

- **Groundwater level analysis:**

  Longer time groundwater level analysis to get better understanding about groundwater level changes characteristics. Analyze the time of groundwater anomalies and seismic strain rate.

- **Typhoon (barometric pressure) analysis:**

  Analyze the groundwater level anomaly on the other typhoon events

- **Sea tide analysis:**

  Signal decomposition to get the groundwater level data without sea tide effect

- **Earthquake analysis:**

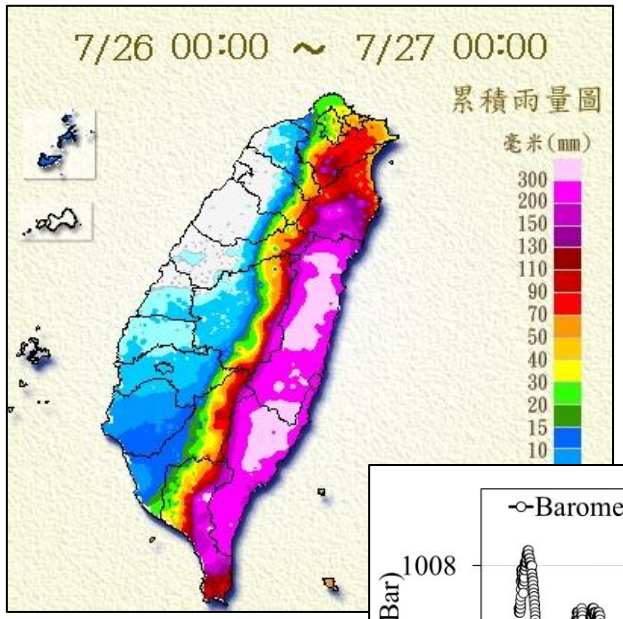
  Analyze the co-seismic groundwater level anomaly in the earthquake events.

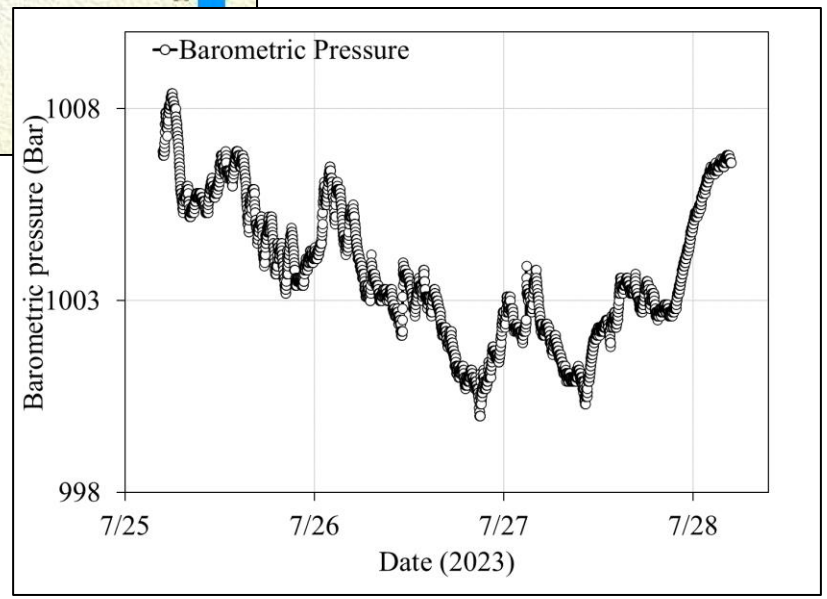
Thank you

Events Related to the Groundwater Anomalies

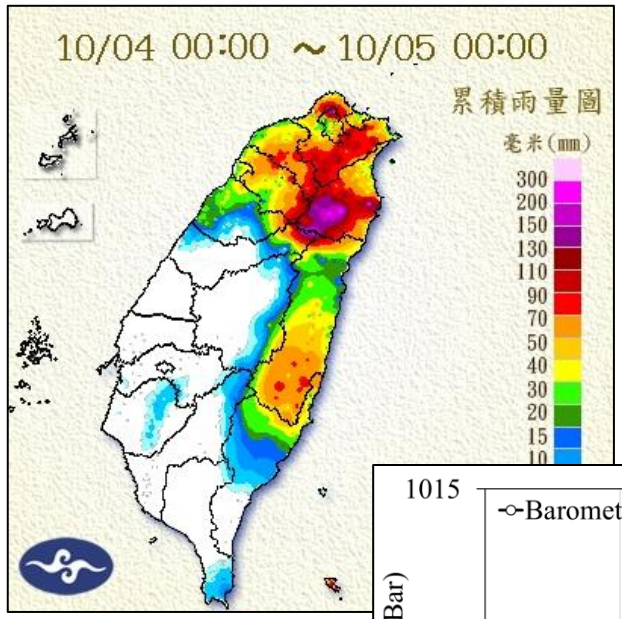
Other typhoon affect Hualien area

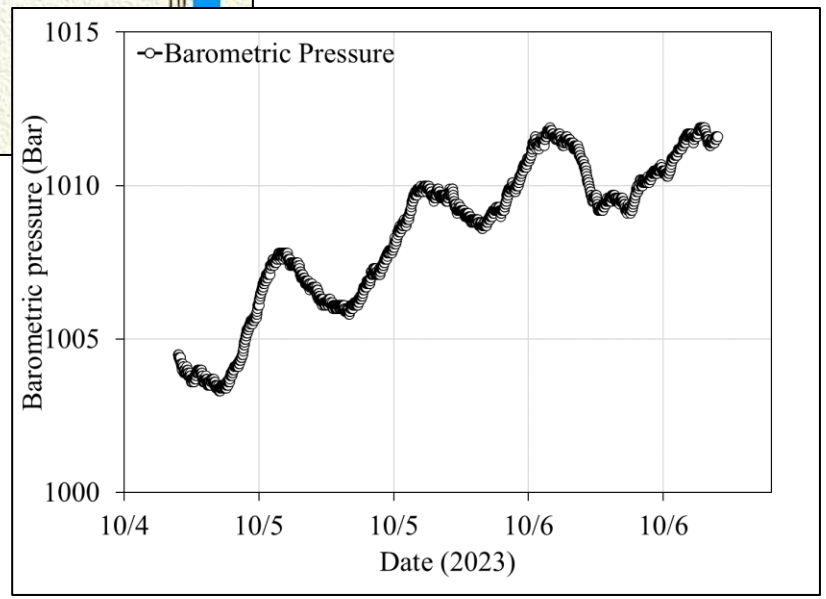
DOKSURI





KOINU





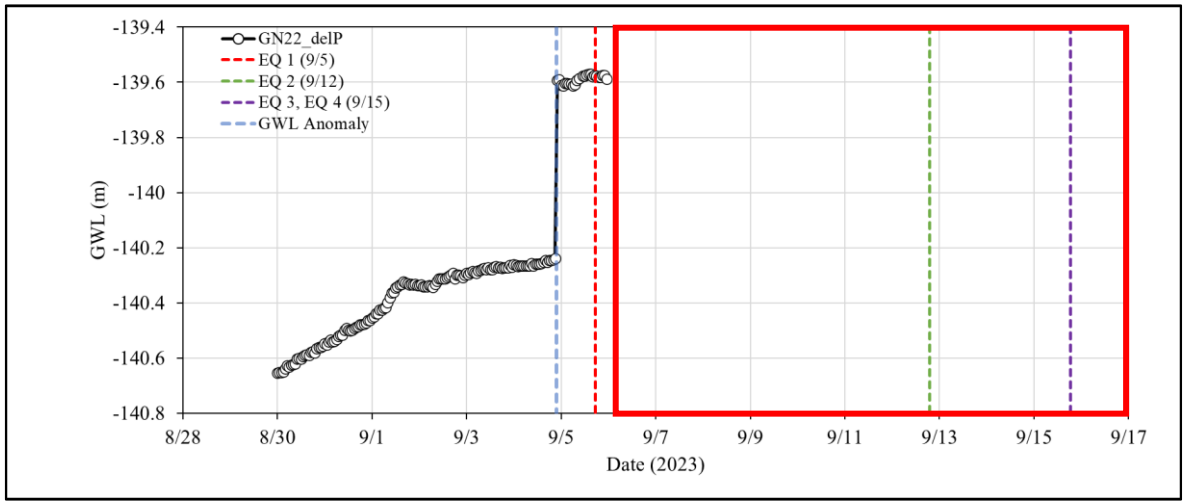
Strain Rate

Strain rate refers to the rate at which deformation of a material occurs under stress. In the context of geology, strain rate measures how quickly the shape or volume of a rock or a portion of the Earth's crust changes over time, typically due to tectonic forces such as the movement of Earth's plates. This measurement is crucial for understanding the dynamics of earthquakes and fault lines, as it can indicate how much stress is accumulating in the crust and may help predict seismic activity. Strain rates are usually expressed in units of inverse seconds (/s), indicating how quickly the deformation happens over a given time period.

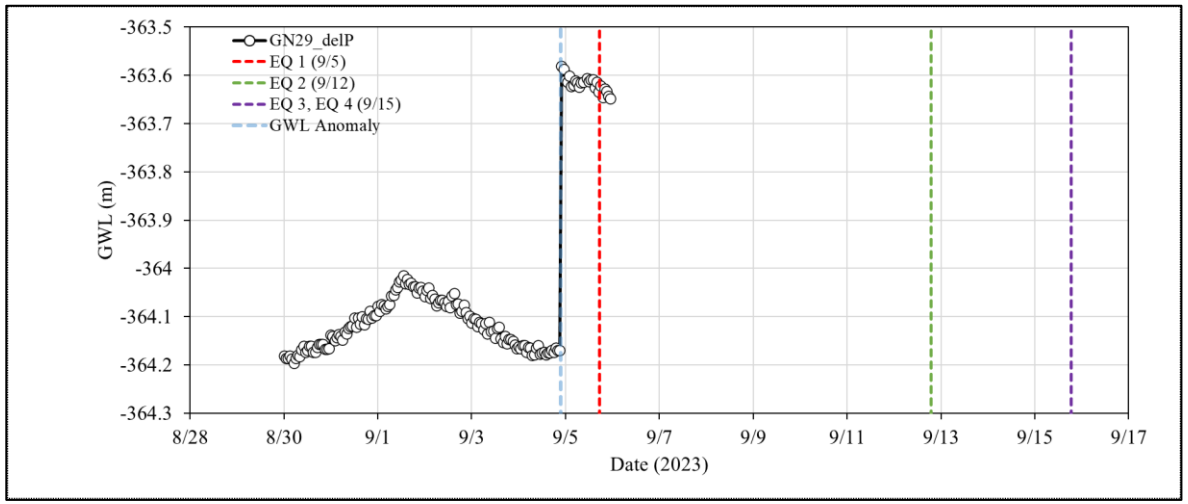
Events Related to the Groundwater Anomalies

Earthquake Events

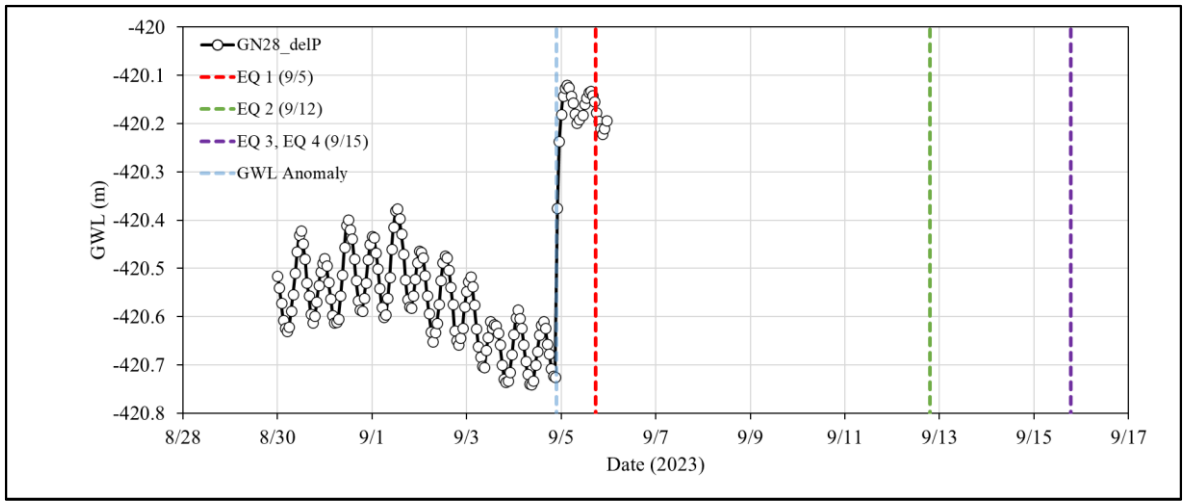
Depth :170 m

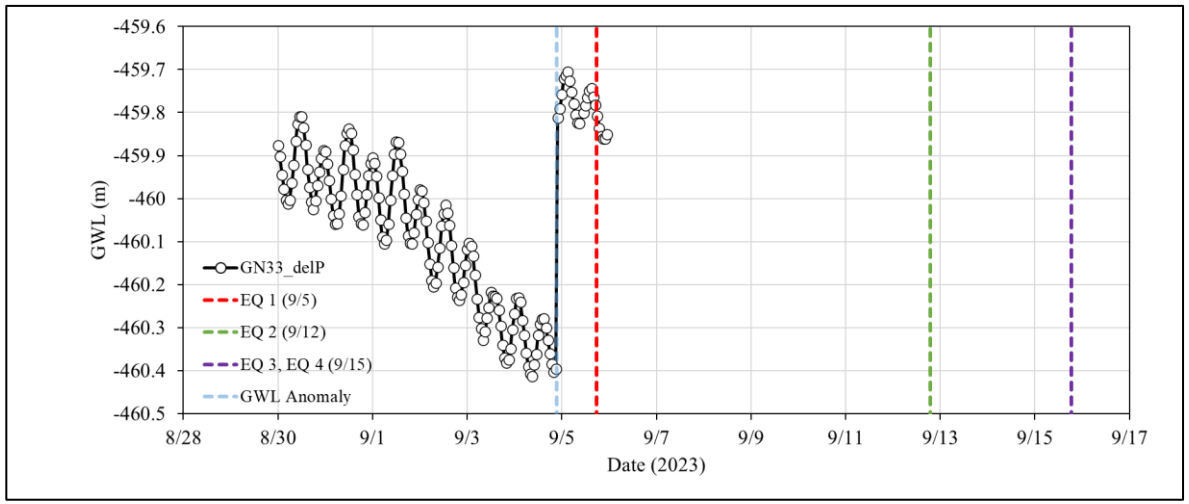


Depth :360 m



Need further groundwater level data to analyze how the strain rate affect the groundwater level changes.





Disclaimer

Even if such anomalies are observed in several wells, it is still impossible to estimate the magnitude, epicenter, or timing of an anticipated earthquake in the absence of additional data (Matsumoto et al., 2007) .