Seismic Response of Dissolved Gas in Groundwater

F. Tsunomori[1], H. Tanaka[2], M. Murakami[2], and S. Tasaka[3]

[1]GCRC, Graduate School of Science, University of Tokyo

[2]Department of EPS, Graduate School of Science, University of Tokyo

[3]Faculty of Education, Gifu University

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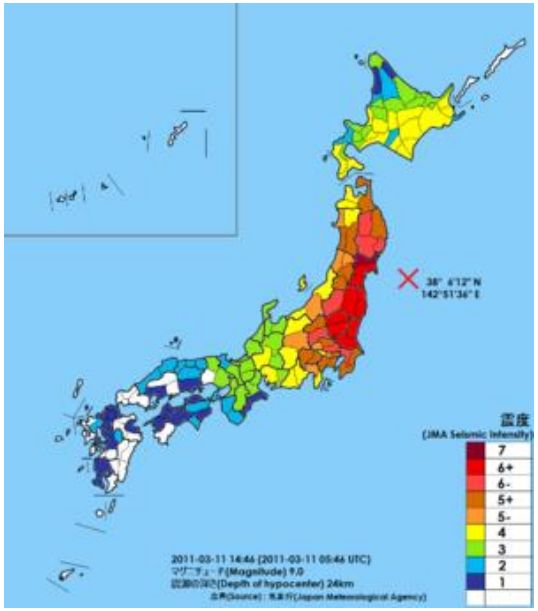
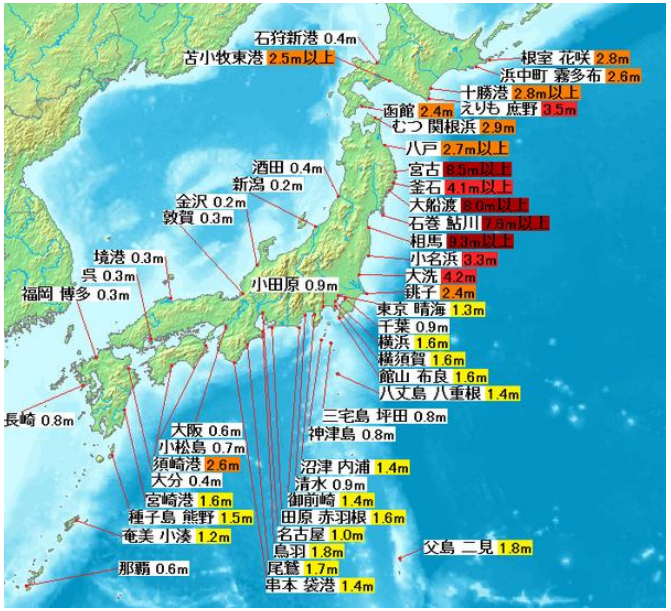
The 3.11 Tohoku earthquake

- The 2011 off the Pacific Coast of Tohoku Earthquake (M9.0) on March 11, 2011, brought fatal tsunami damages to the coast area of the Tohoku district.





- No pre-seismic anomaly was reported officially.

Preface

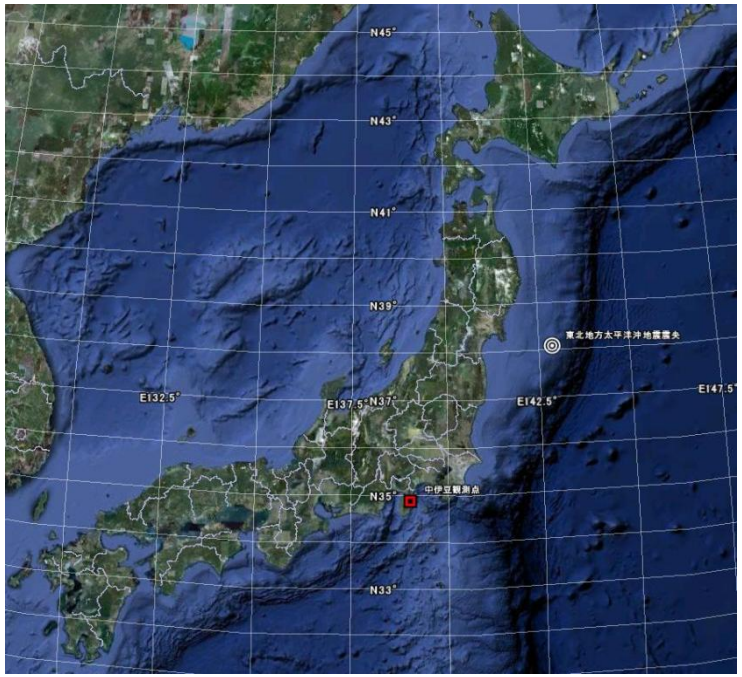
- We cannot prevent earthquakes, but I believe that the earthquake forecast will reduce damages after the event. So we have to keep trying to realize the earthquake forecast.
  - The radon concentration change would be one of powerful tools to catch a precursor just before a big earthquake, when the mechanism is clearly understood.

Abstract

- We share three cases of concentration change of dissolved gas in groundwater before the 3.11 Tohoku big earthquake.
  - Radon at the Kashima observatory.
  - Volatile gas at the Atotsugawa observatory.
  - Radon at the Nakaizu observatory.
- I propose anew radon observation principle hybridized with a hydraulic conductivity monitoring in order to investigate a mechanism of the concentration change relating to earthquakes.

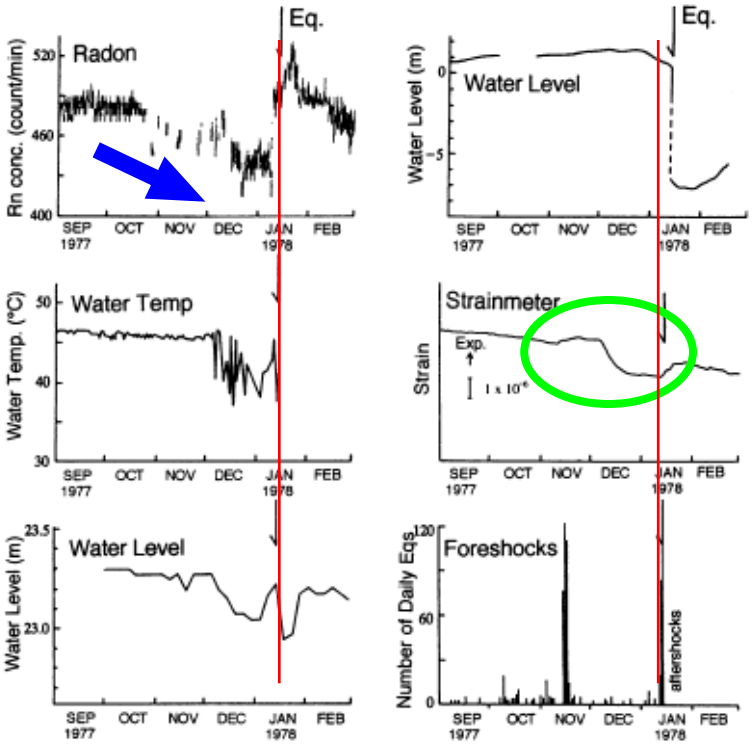
Nakaizu Observatory

- The observation well was drilled in a brittle complex surrounded by a ductile complex in the Izu Peninsula.
- The distance between the epicenter of the 3.11 EQ and the observatory is about 490 km.



Izu-Oshima Kinkai Earthquake, 1978

- Radon decline before the EQ corresponded to other anomalous changes of water temperature, water level and volumetric strain.



Wakita et al. (1980,1996)

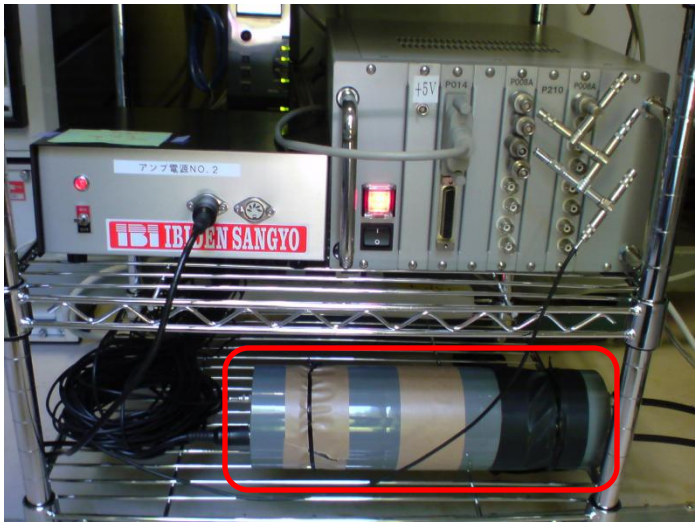
Preliminary Model

- A volatilization model was adopted to the radon decline before the earthquake in 1978. (Tsunomori and Kuo (2010))
  - According to this evaluation, the decrease of radon was explainable in terms of generation of a 2.4% gas phase to the original groundwater volume.

- In order to examine the reliability of this model, we are keeping the radon observation by a new radon monitoring system.

Radon Monitoring at Nakaizu

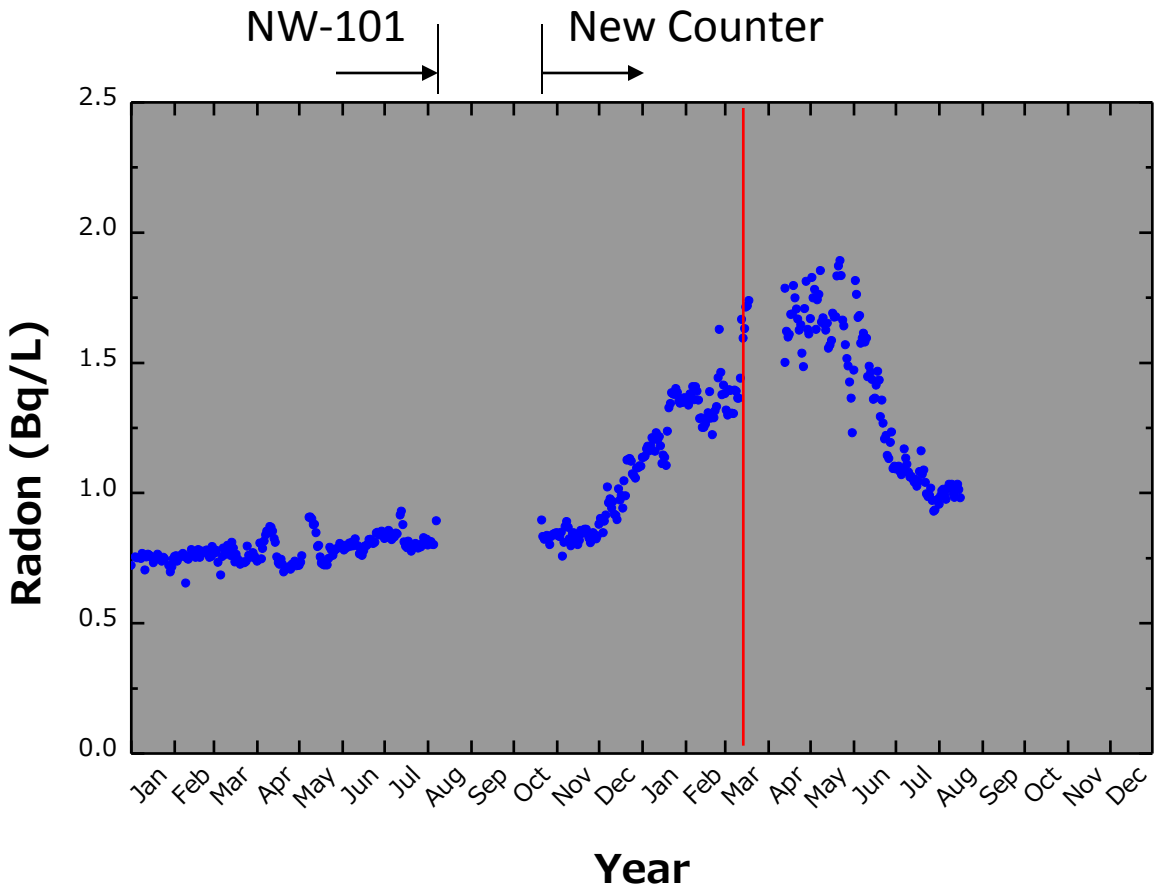
- The radon concentration was measured with a new radon counter (ZnS:Ag).
- Dissolved radon was extracted with a counter flow extractor.



Radon Counter

Variation of Radon before the 3.11 EQ

- The radon concentration increased from about 3 months before the 3.11 EQ.



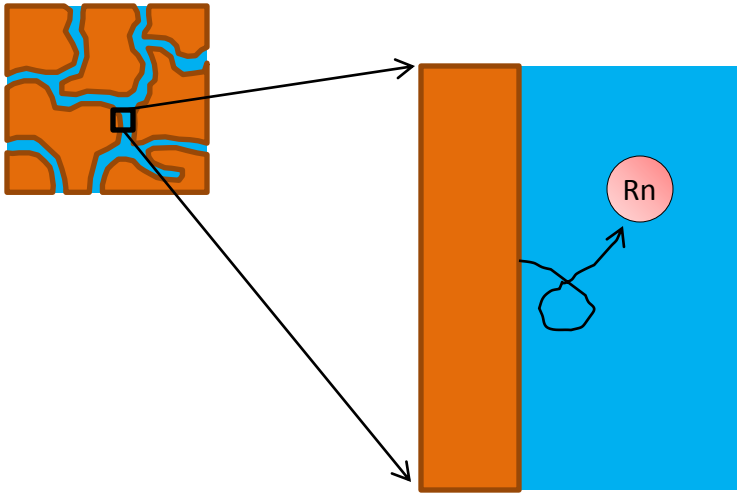
10 Years Record of Radon

- We hesitate to profess this phenomenon to be a preseismic anomaly, because no other anomalous change was reported officially in the corresponding period.

It is very important to comprehend a time series of the radon concentration in terms of a suitable model even in inter-seismic period.

Radon in Groundwater

- Radon in groundwater is released only from the rock surface.
- Radon concentration is a function of a surface area and a fluid volume in an aquifer.



Emanation power

Half life

Surface area

$$C_0 = \tau E \frac{S}{V_p}$$

Fluid volume

$$v_0 = \frac{V_p}{V}$$

Unit volume = 1

Fluid volume fraction

$$\frac{C_w}{C_0} = \frac{1}{1 + HS_g}$$

Kuo et al. (1996)

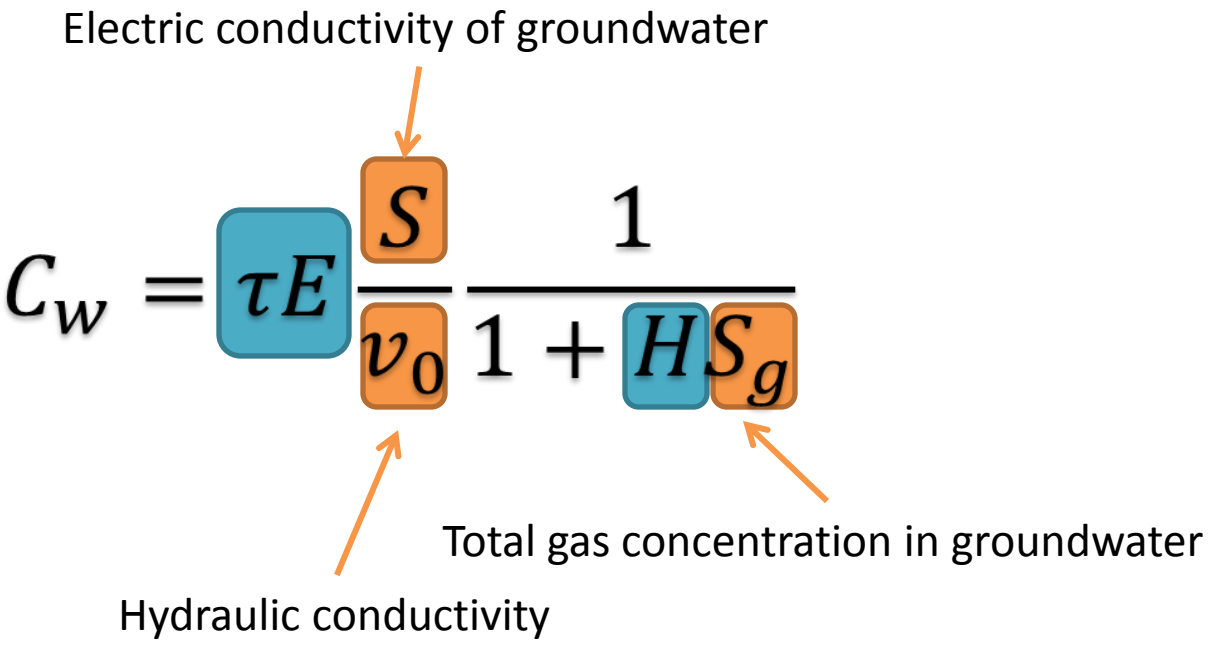
Henry's coefficient

Gas saturation

$$C_w = \tau E \frac{S}{v_0} \frac{1}{1 + HS_g}$$

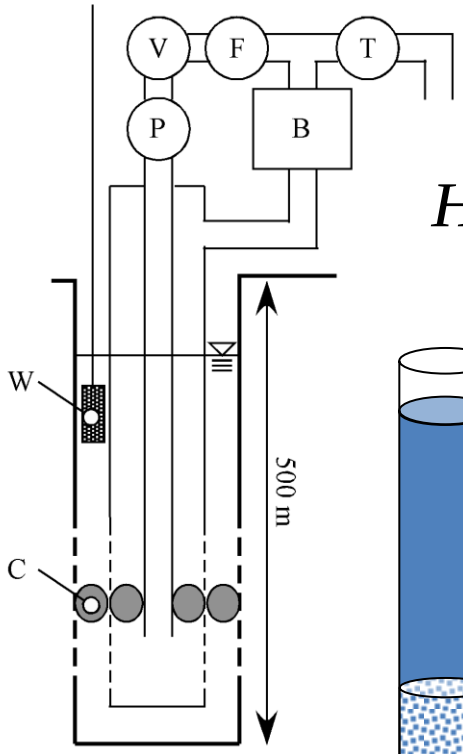
Radon in Groundwater

- If this model is correct …

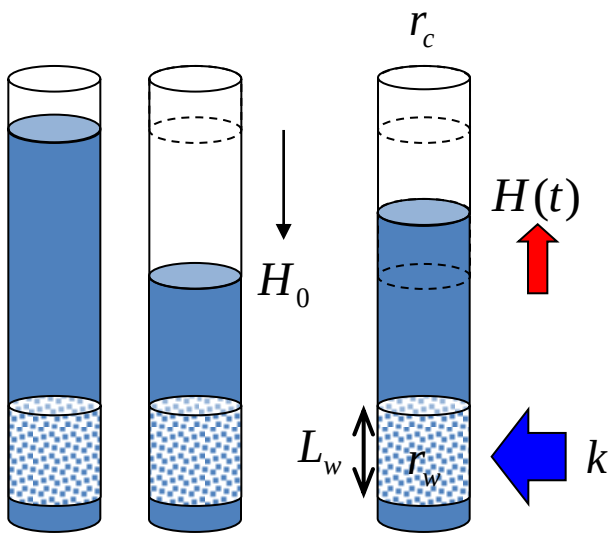


- We propose anew radon observation hybridized with monitoring of the hydraulic conductivity, the electric conductivity and the total gas concentration in groundwater.

Observation of Hydraulic Conductivity



$$H(t) = H_0 \exp\left(-k^{-1}t\right)$$



$H(t)$: Groundwater recovery curve

k : Recovery rate

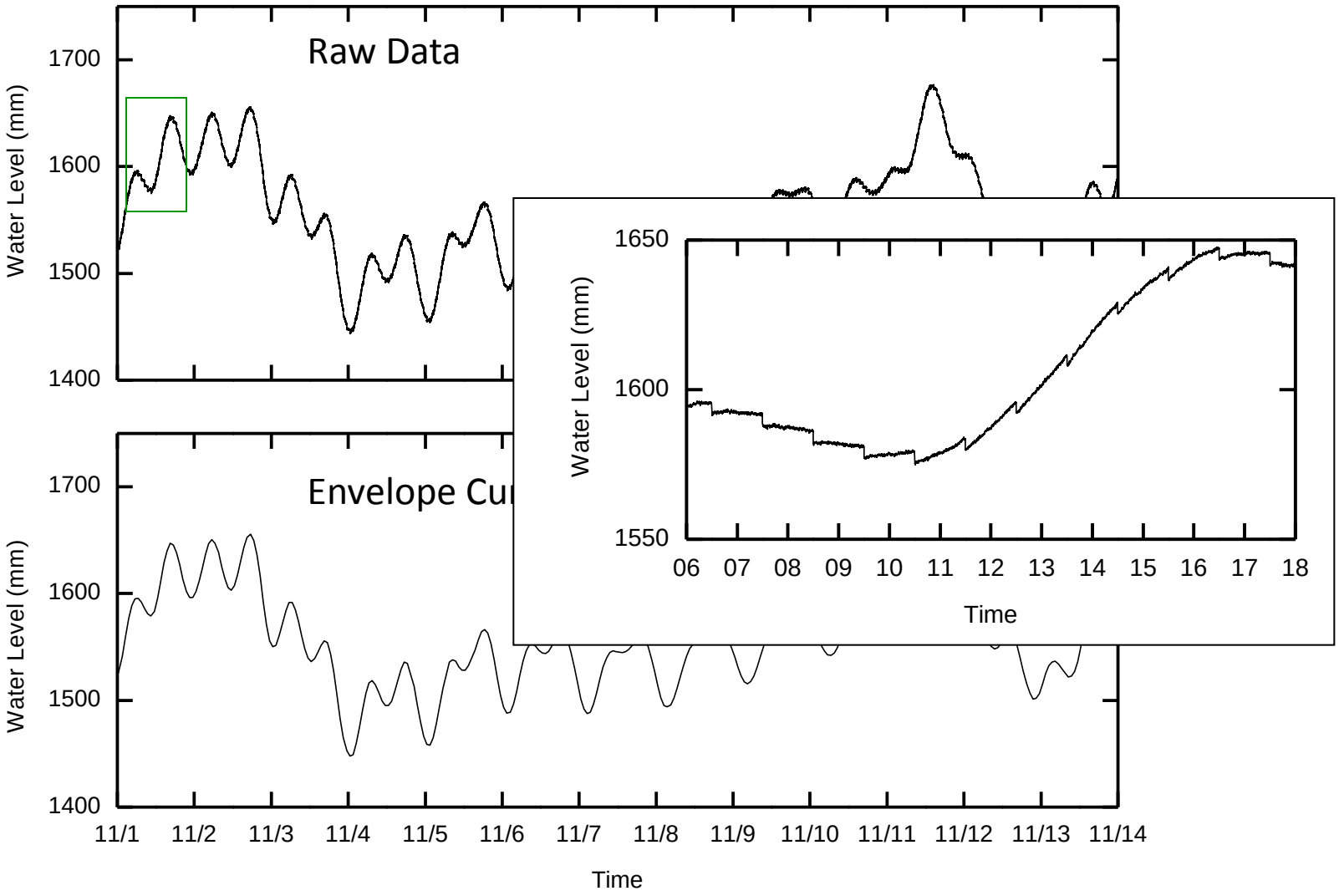
H_0 : Initial groundwater level

$$k = \frac{r_c^{\,2}}{2KL_w} \ln\left(\frac{1}{2}\frac{L_w}{r_w} + \sqrt{1+\left(\frac{L_w}{r_w}\right)^2}\right)$$

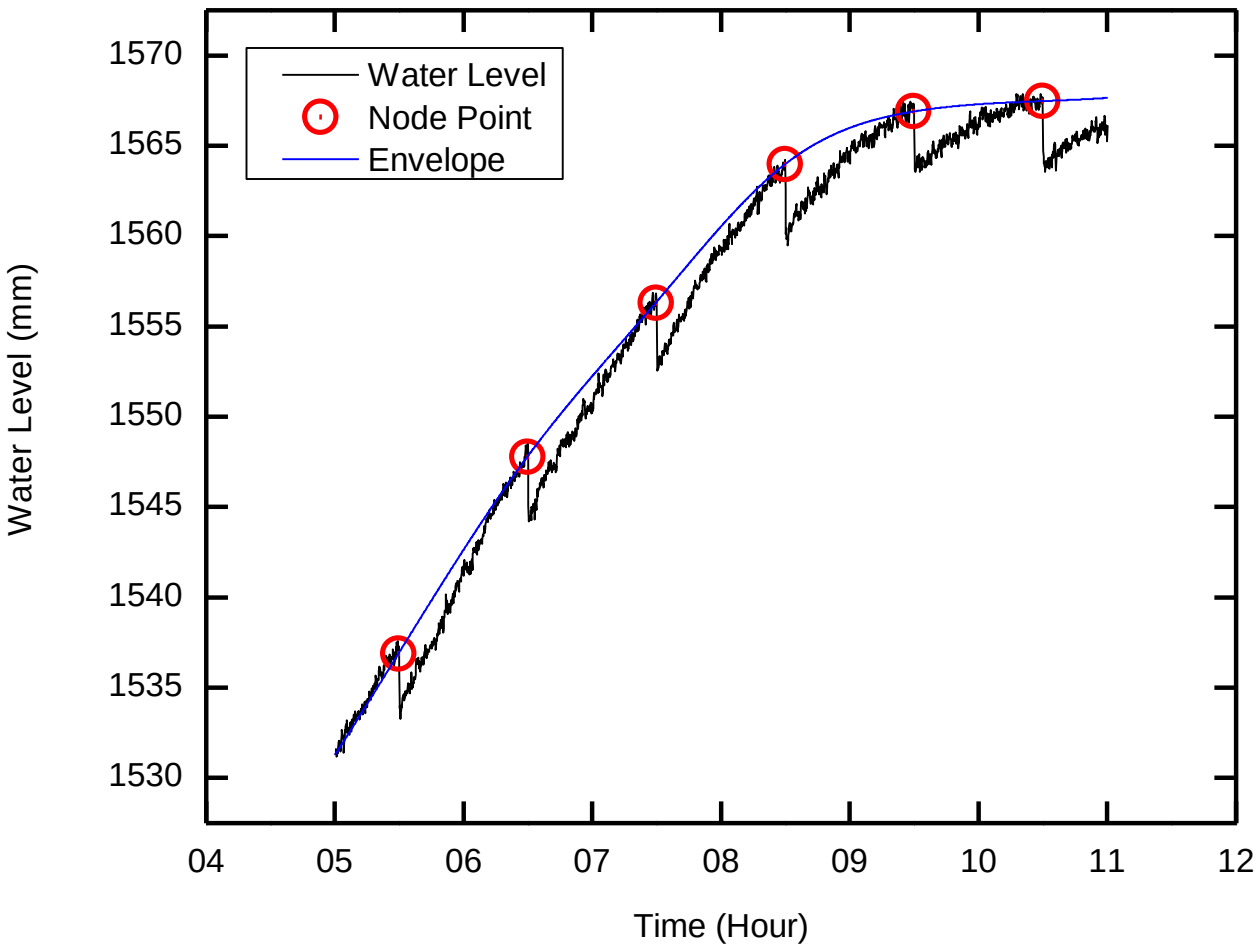
Hvorslev (1951), Wylie (1990)

- This method tends to overestimate, but we started from this method.

Water Level Change at Kamakura

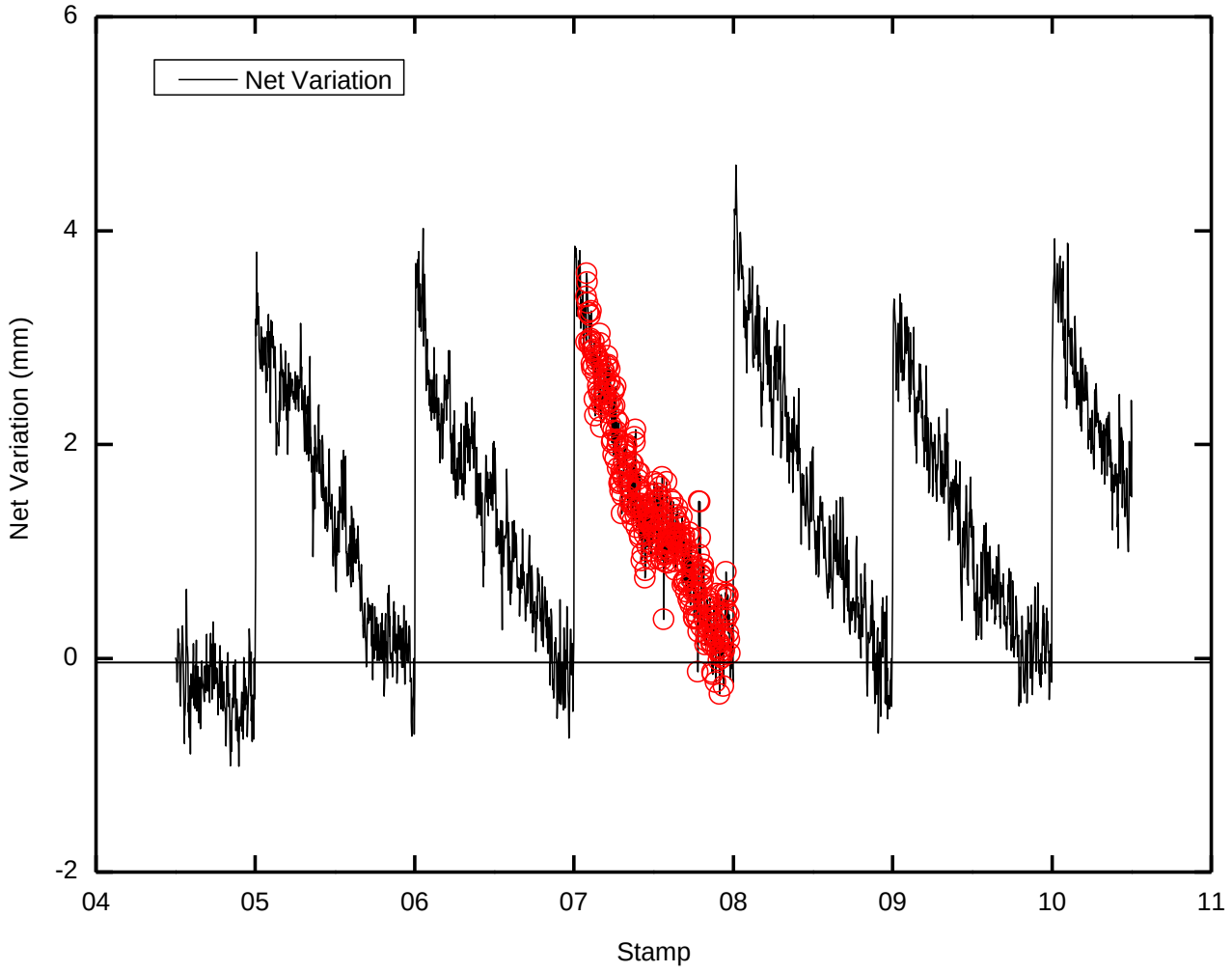


Raw Data and Trend

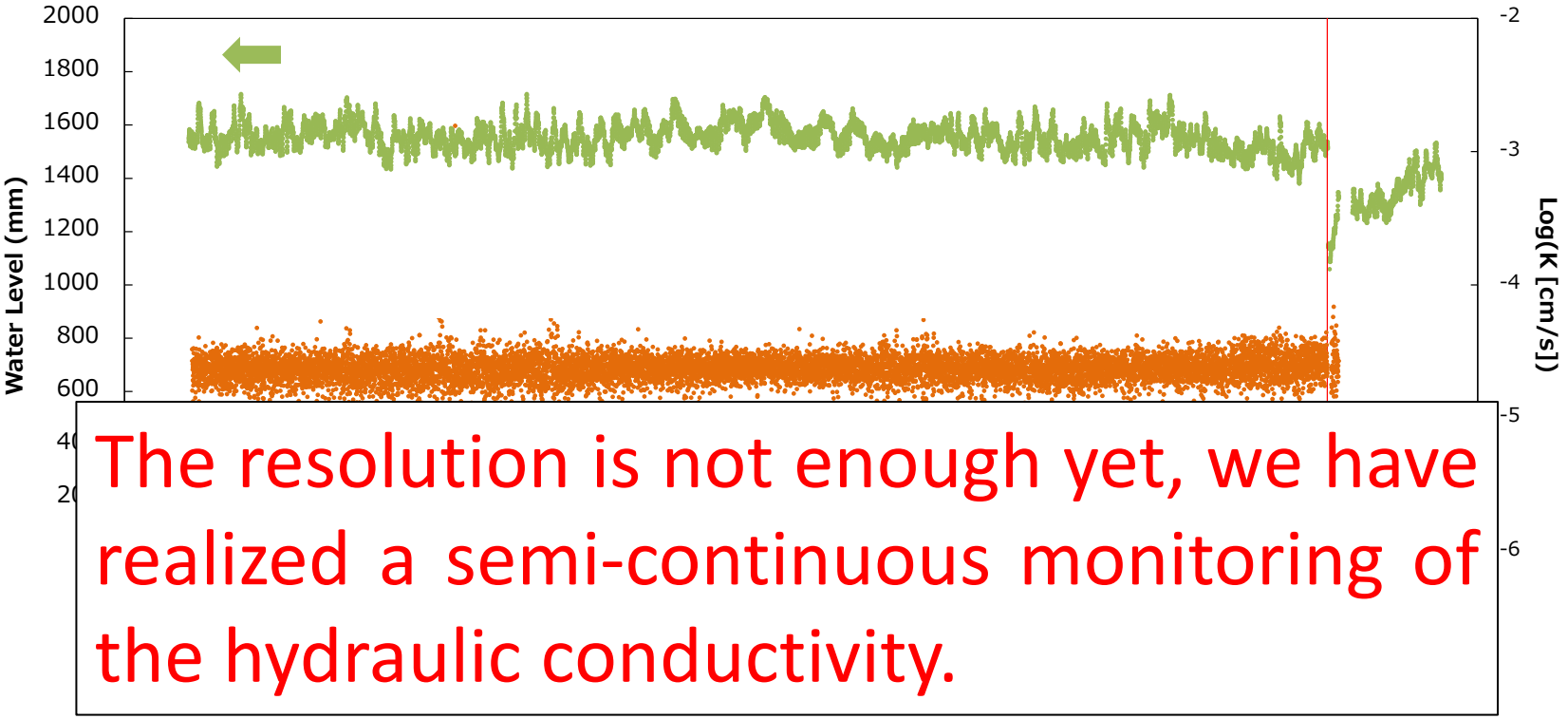


Supposing that the trend of a groundwater level changes smoothly.

Net Variation of GW Level



Preliminary Result



The resolution is not enough yet, we have realized a semi-continuous monitoring of the hydraulic conductivity.

> The hydraulic conductivity calculated from the GW recovery was stable.
> The mean value of hydraulic conductivity was 2.3×10^{-5} cm/s.
> No anomalous change was detected in the water level and the hydraulic conductivity before the 311-EQ.

Conclusions

- We have shared a radon concentration change in groundwater of Nakaizu observatory before the 3.11 Tohoku big earthquake.
  - Radon concentration recorded at the Nakaizu observatory might be a precursory change.
  - We have to keep investigating the mechanism of such phenomenon.
- Anew radon observation has been proposed.
  - The radon monitoring with hydraulic conductivity measurement has been successfully conducted.
- The radon concentration measurement based on the physical model will be important to make the method reliable in the future.