

# Underground Water Observation in “Wari-ishi Hot Spring”, Central Japan

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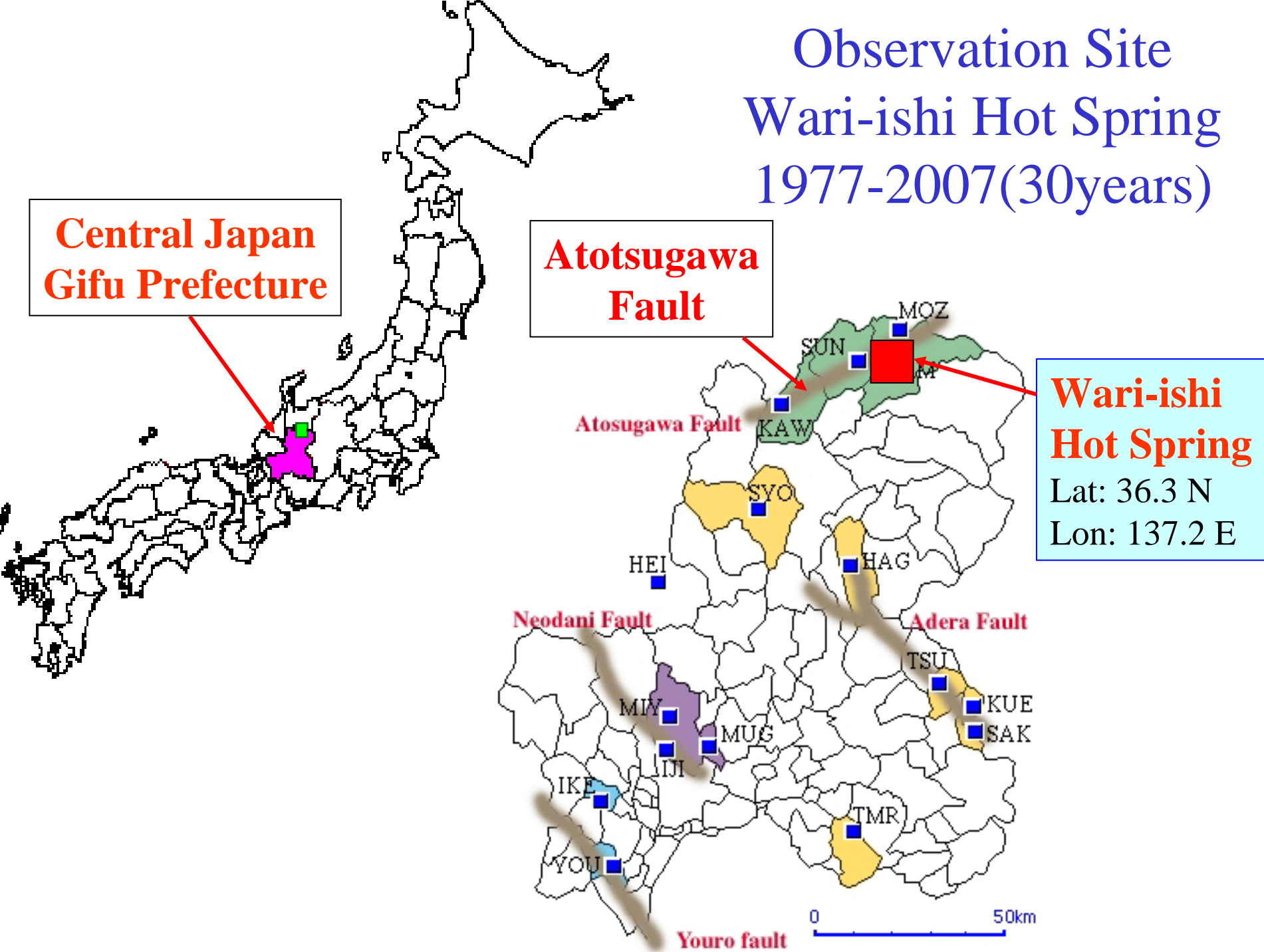
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# Observation Site Wari-ishi Hot Spring 1977-2007(30years)

Central Japan  
Gifu Prefecture

Atotsugawa  
Fault

Wari-ishi  
Hot Spring  
Lat: 36.3 N  
Lon: 137.2 E



# Underground Water observation System

1st period:1977-1998

Observed by Bucket and Stopwatch(every Monday)

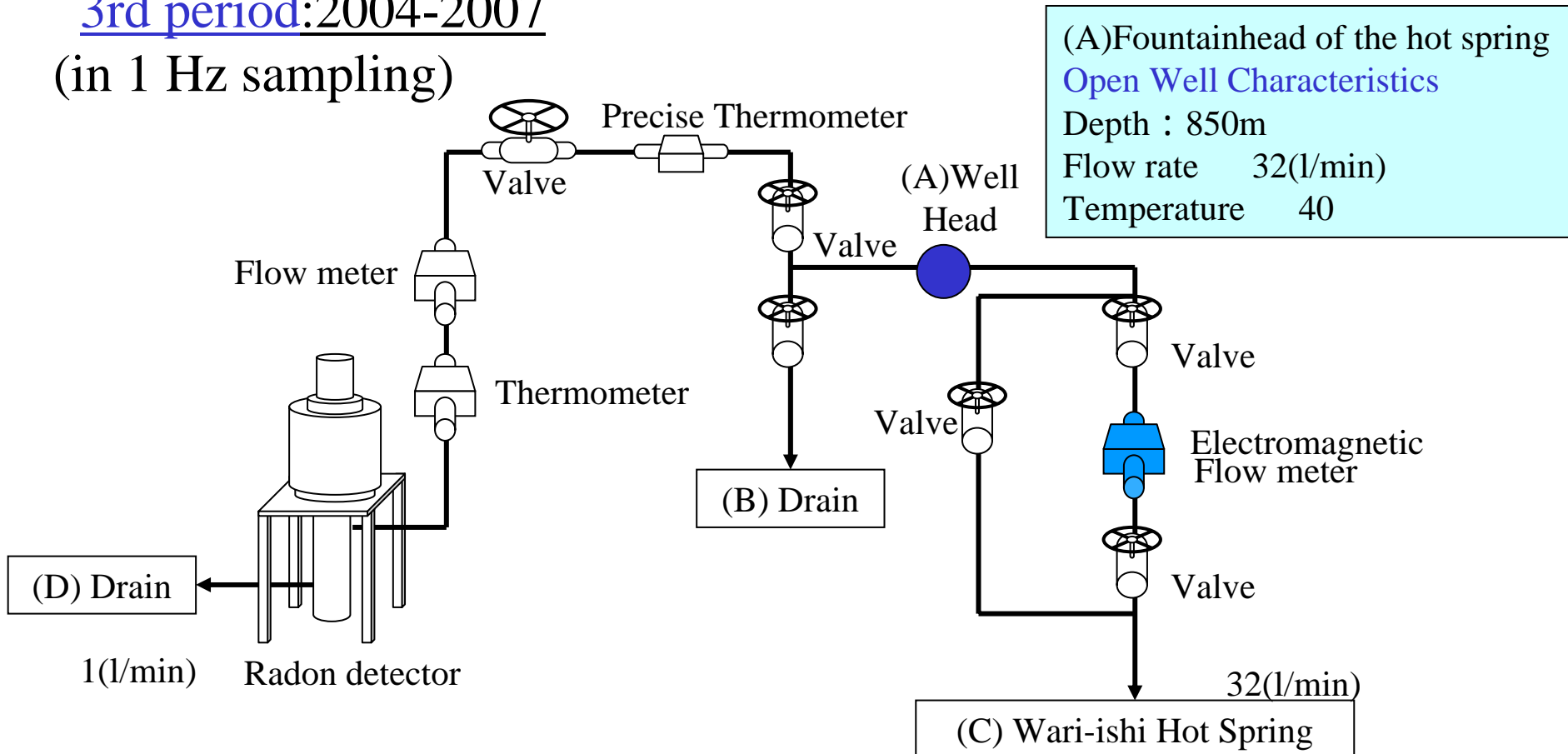
2nd period:1998-2003

Electromagnetic Flow Meter

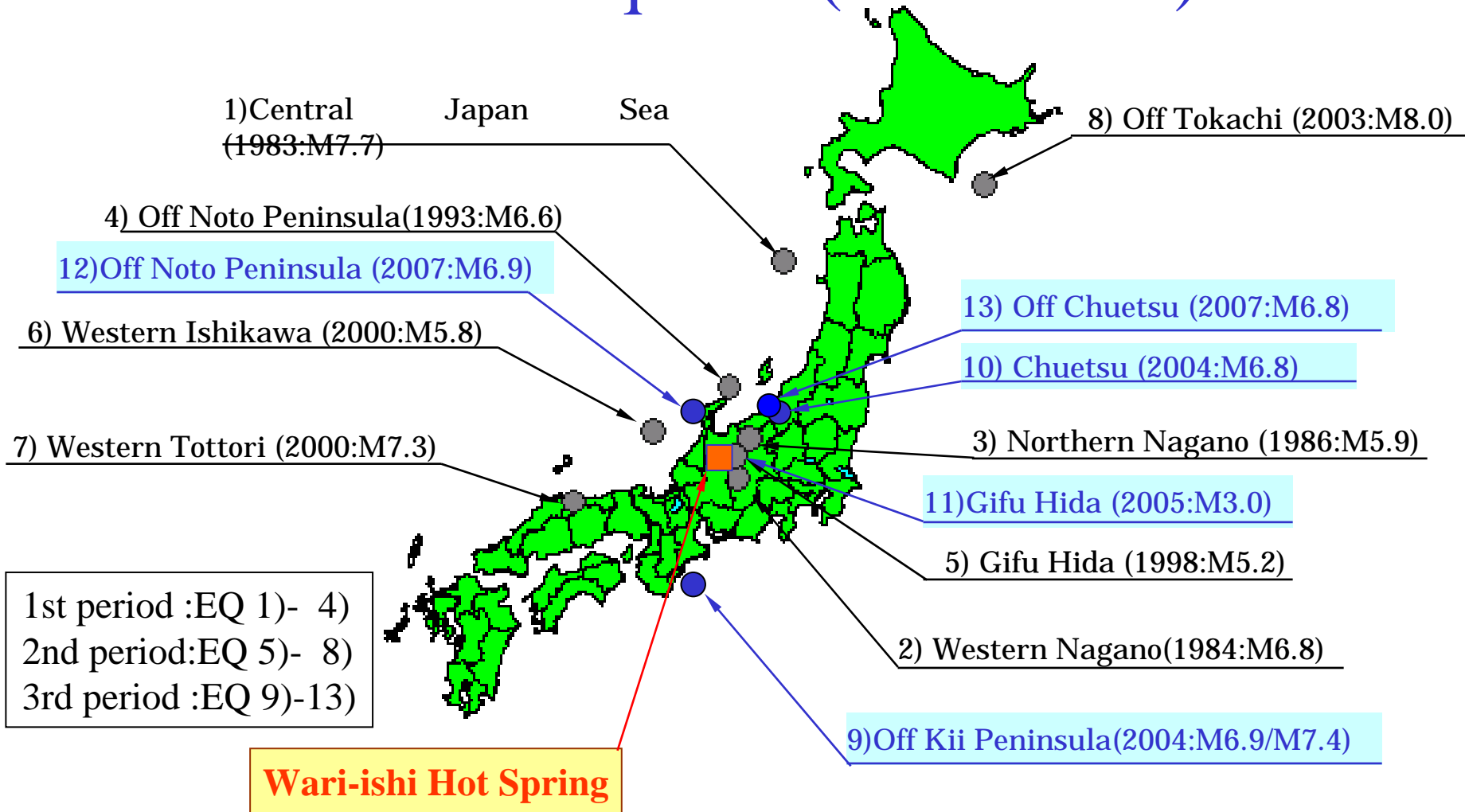
(with continuous measurement in 10 min interval)

3rd period:2004-2007

(in 1 Hz sampling)

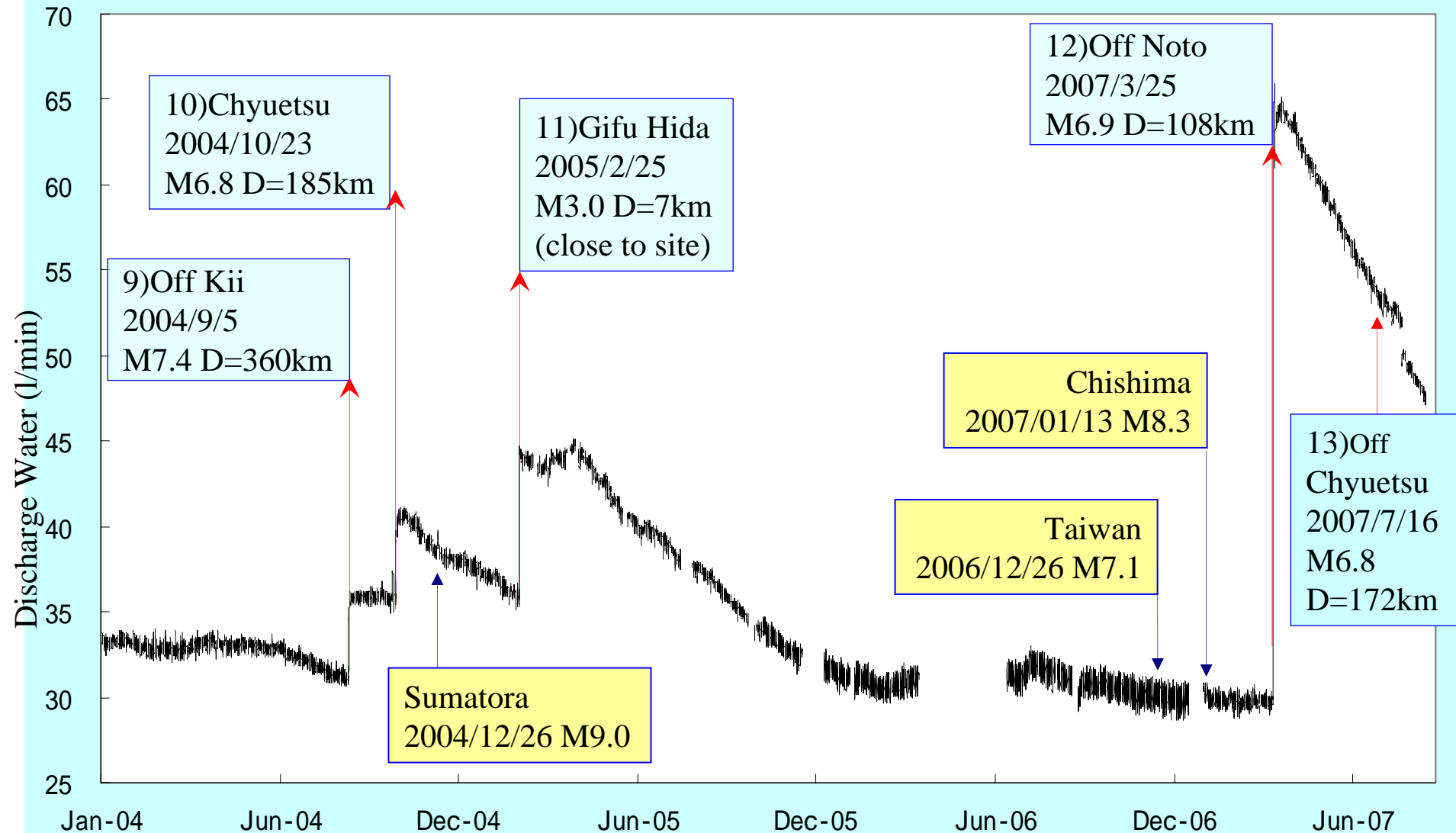


# Co-seismic Changes of Discharge Water with Earthquakes(1977-2007)

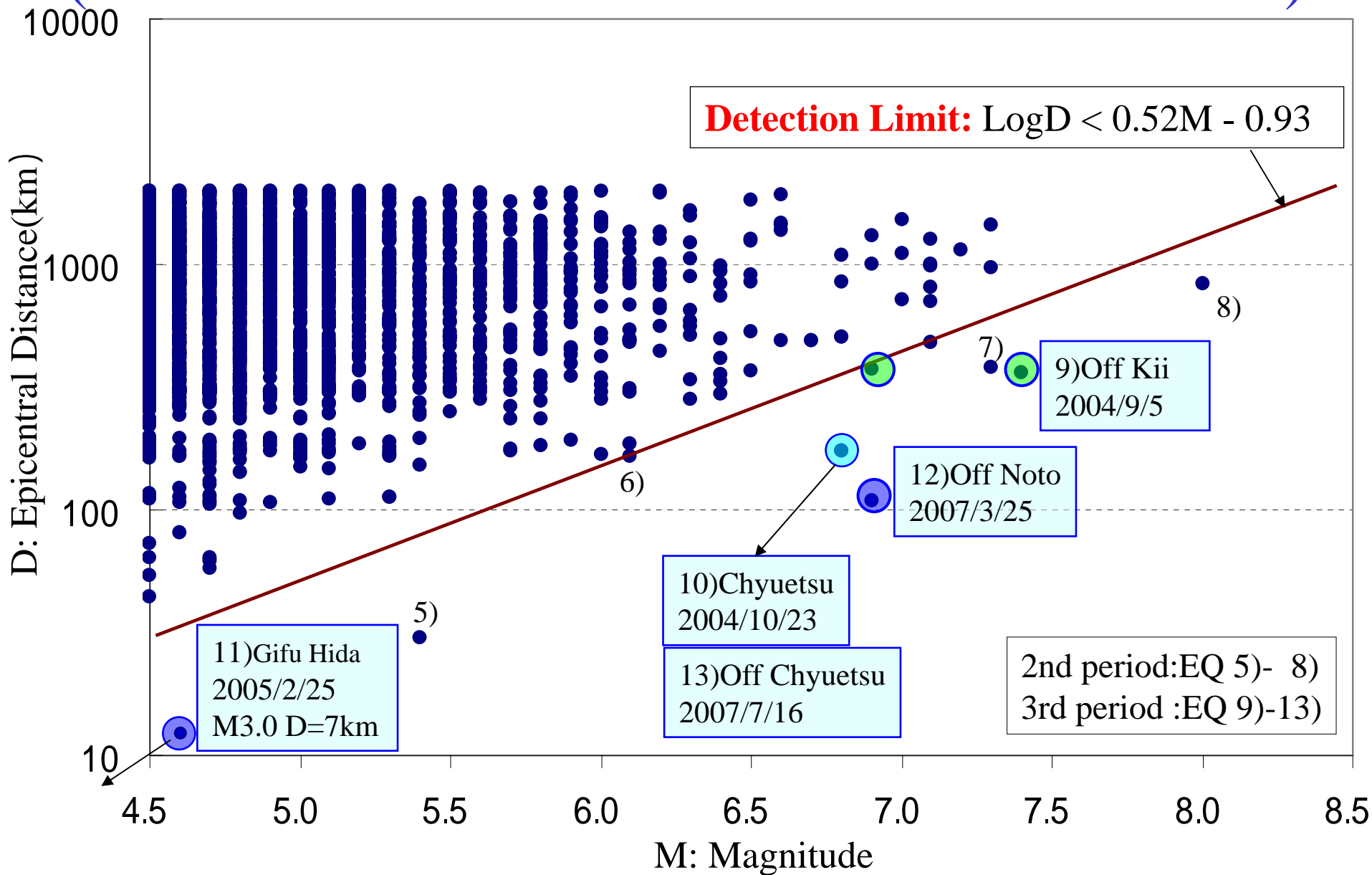


See presentation for 1st and 2nd period observation results on this Workshop 2004, from <http://www.gsj.jp/GDB/openfile/files/no0420/presentations/05-Tasaka.pdf>

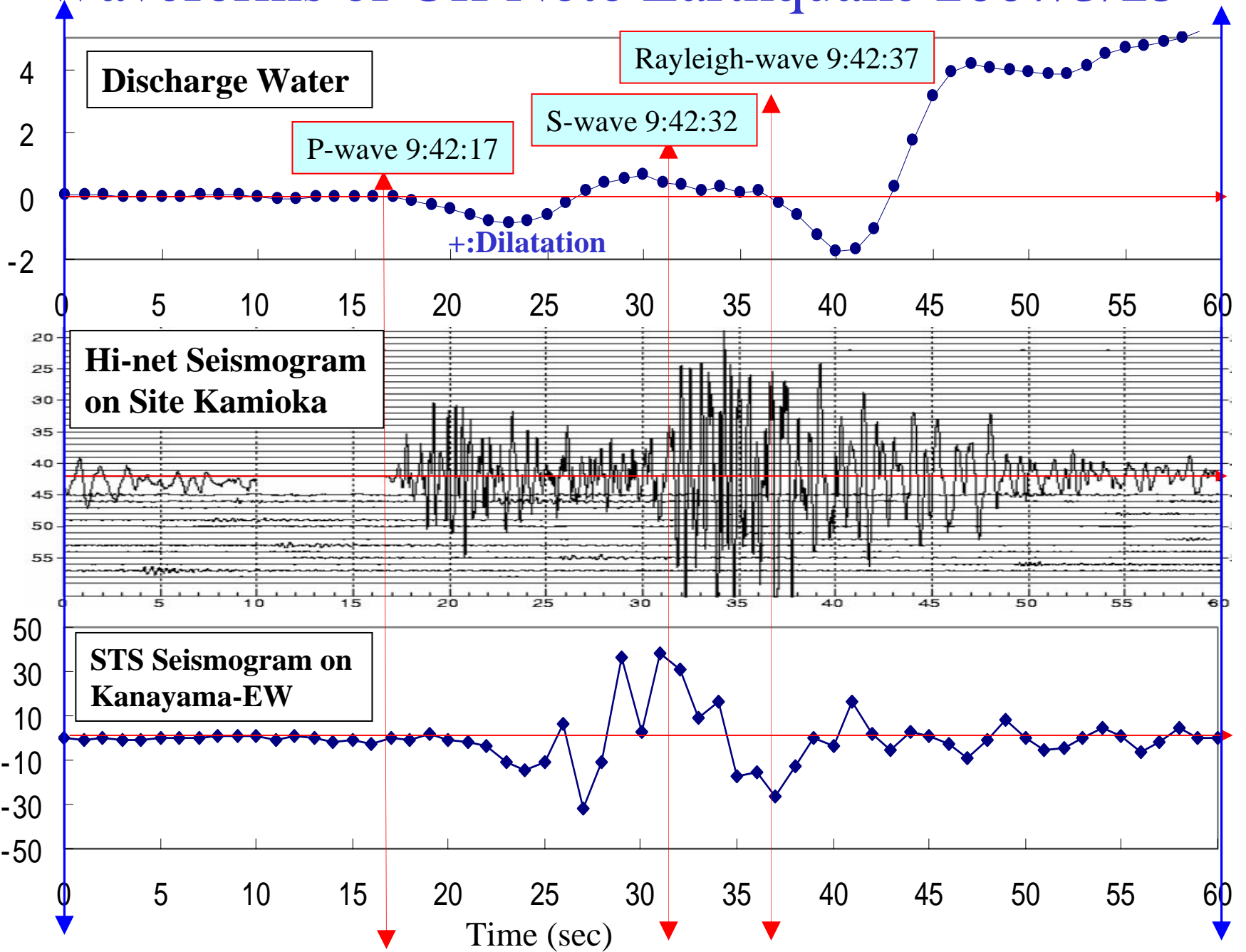
# Discharge Water in Wari-ishi Hot Spring (3rd Observation Period:2004-2007)



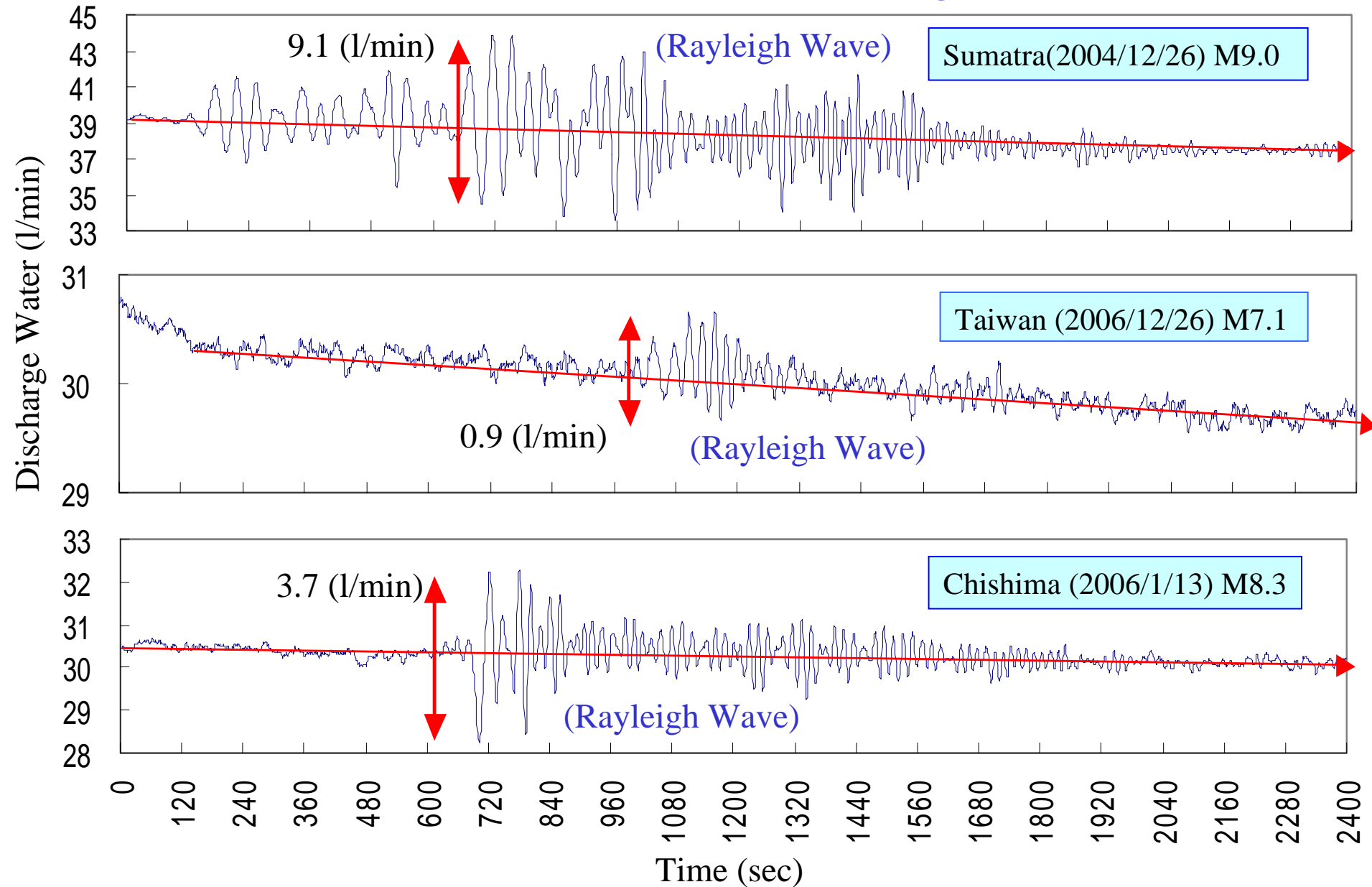
# Detection Limit in Discharge Water Change (2nd and 3rd Observation Period:1998-2007)



# Waveforms of Off Noto Earthquake 2007/3/25

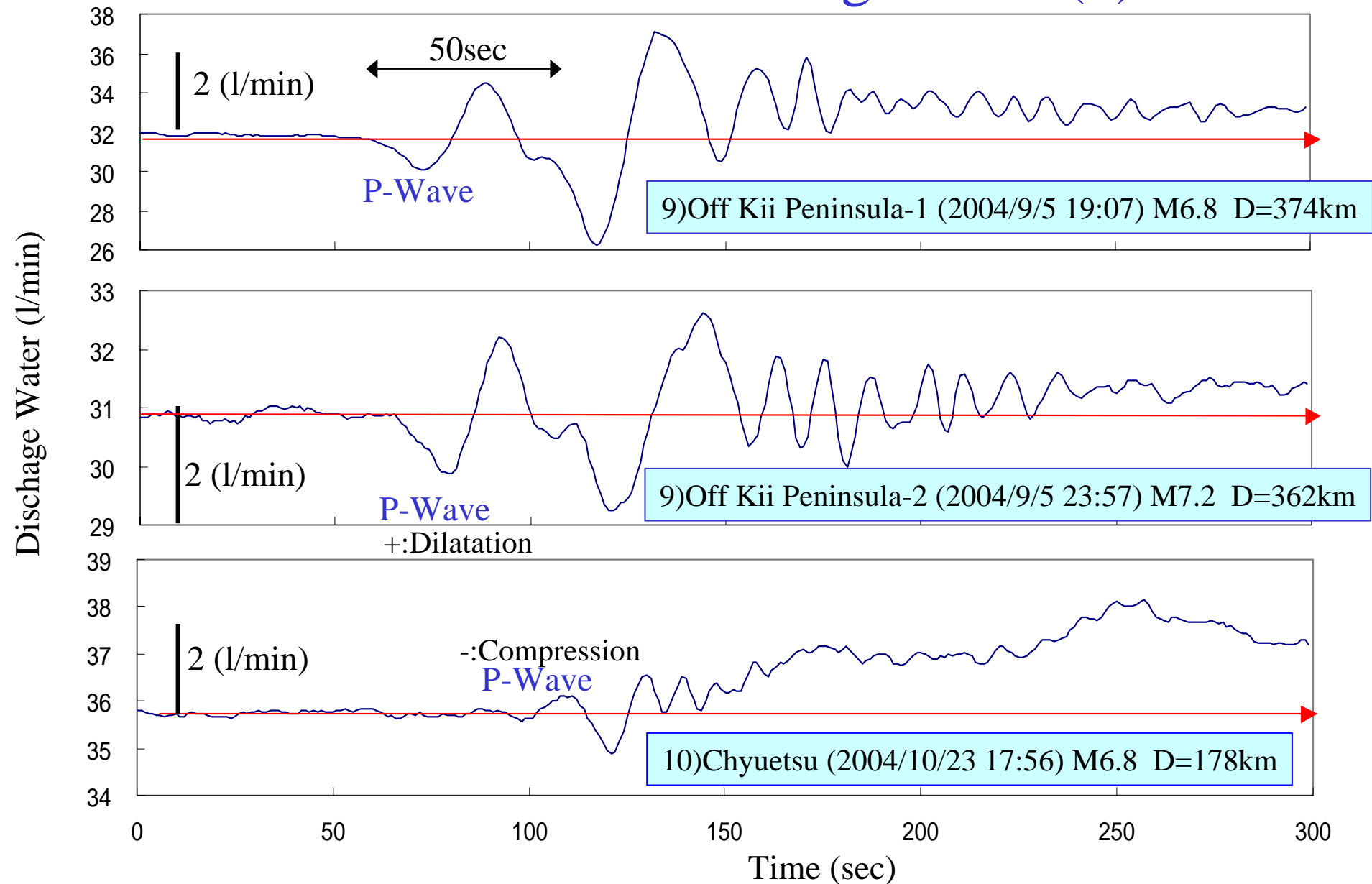


# Hydro-seismic Waveforms of Far Big Earthquakes with 1 Hz Data Taking

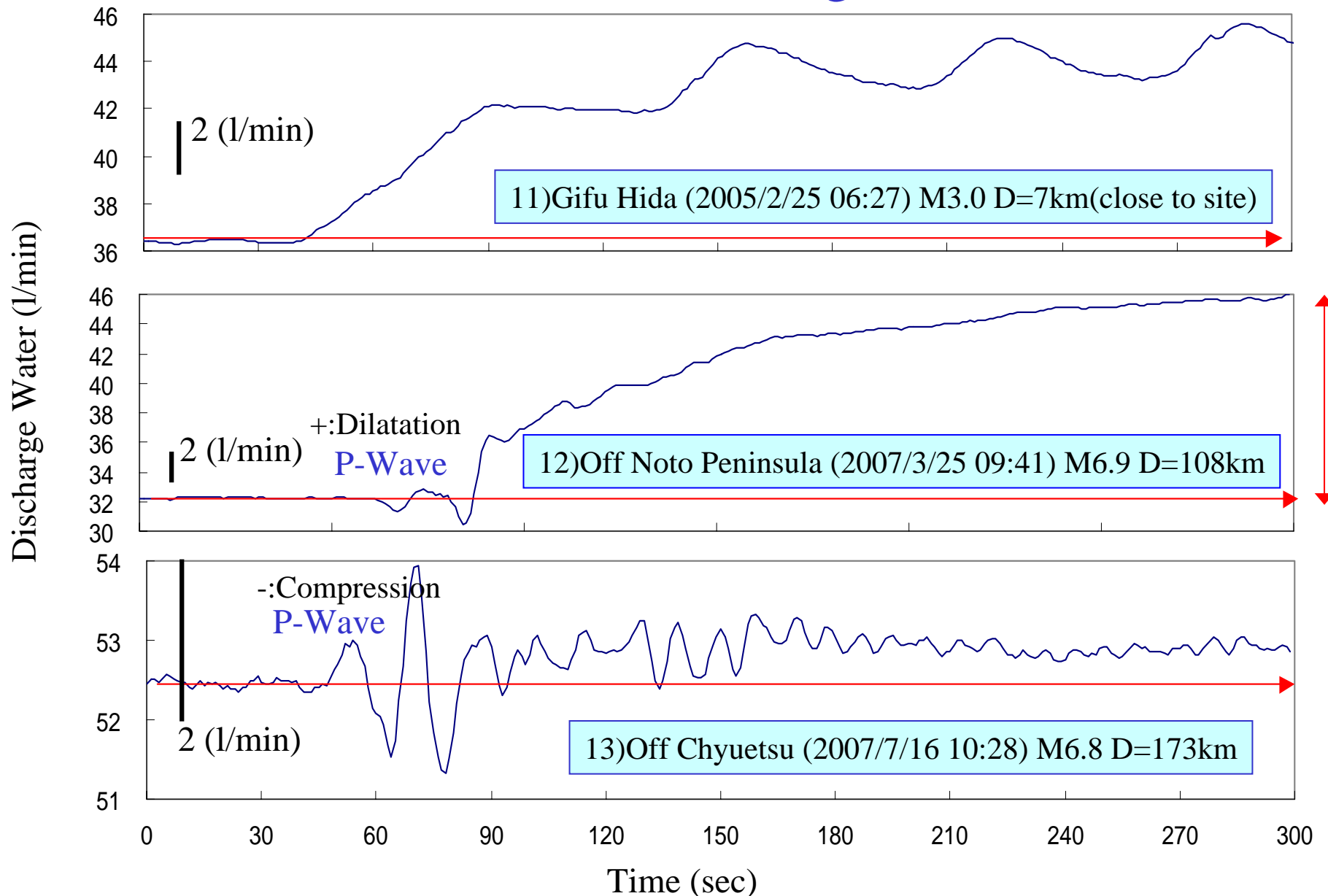




# Hydro-seismic Waveforms of Near Earthquakes with Increase of Discharge Water(1)



# Hydro-seismic Waveforms of Near Earthquakes with Increase of Discharge Water(2)



# Tidal Response

2nd and 3rd period:1998-2007

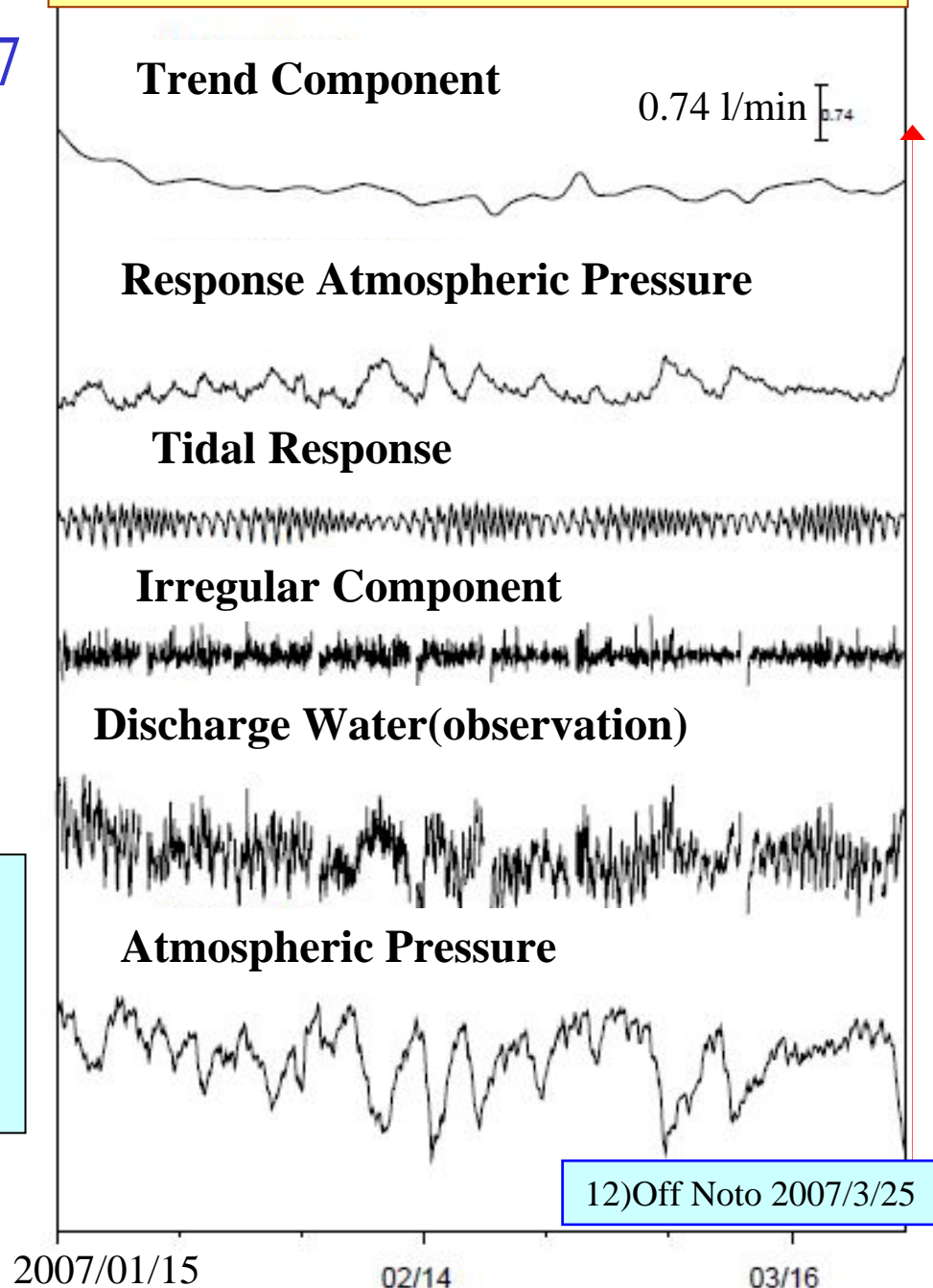
Flow Rate/Discharge Water  
Atmospheric Pressure

Tidal Response  
BAYTAP-G

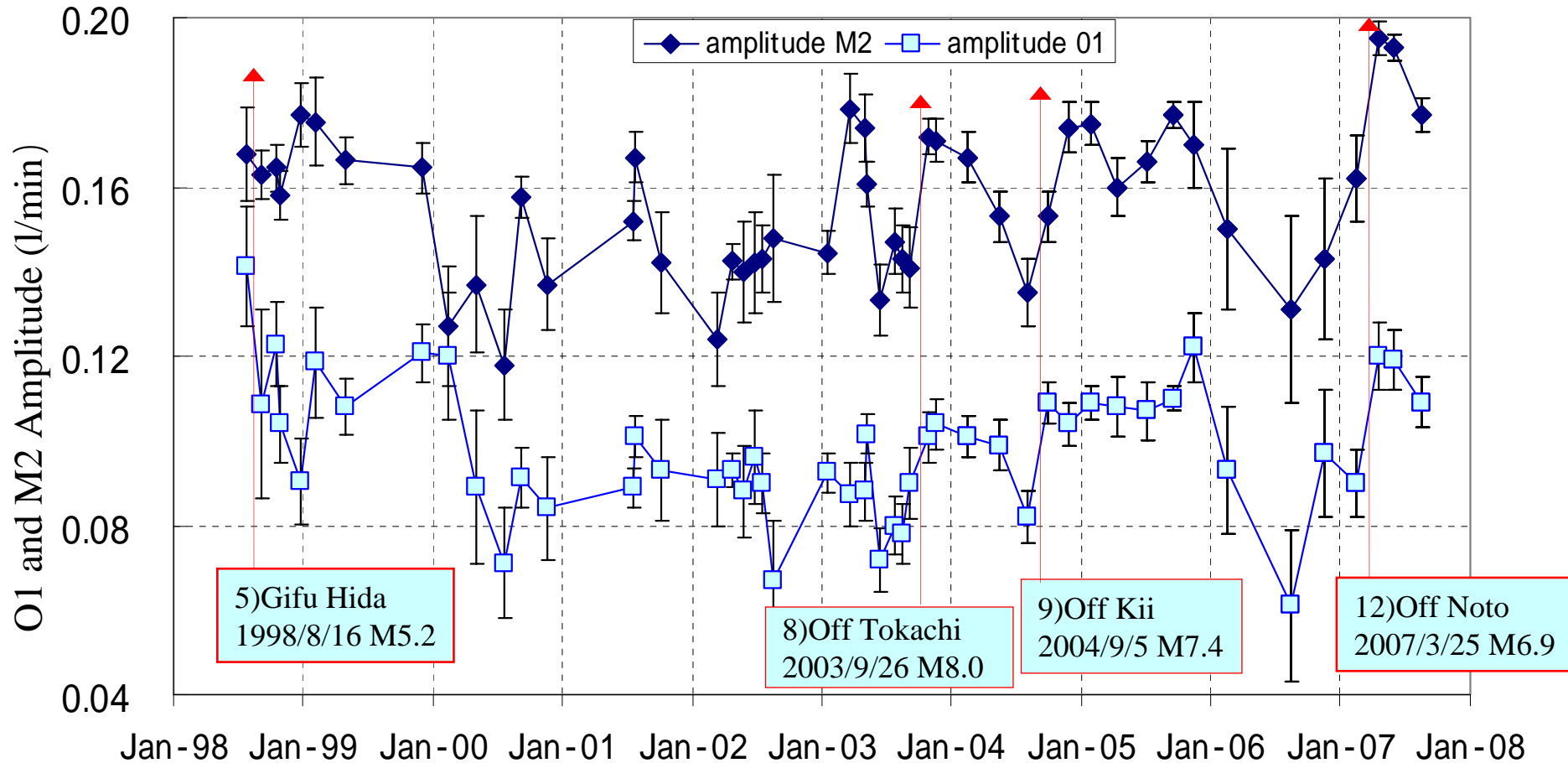
Flow Rate  
•Trend  
component  
•Atmospheric  
component  
•Irregular  
component

Tidal strain  
Sensitivity  
Solved Gas

Start and end Time 2007/01/15-2007/3/25



# Tidal O1 and M2 Amplitude(1998-2007)



## 1) Amplitude of Discharge Water in Earth and Oceanic Tide

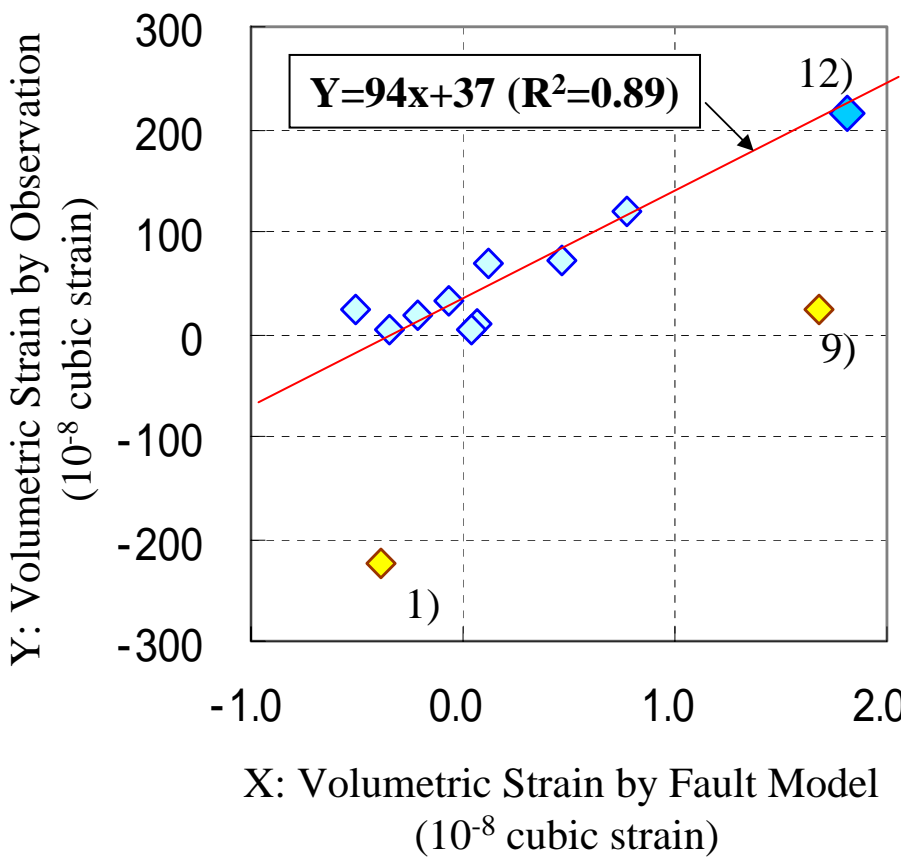
M2: 0.158(l/min) O1: 0.099(l/min)

2) Tidal Strain Calculated by GOTIC2 M2:0.997, O1:0.671(\*10<sup>-8</sup> cubic strain)

3) Sensitivity of Discharge Water M2:0.16, O1:0.15(l/min)/(\*10<sup>-8</sup> cubic strain)

# Co-seismic Change of Discharge Water and Volumetric Strain

Earthquake	M	Dist	Model	Obs
1)Central Japan Sea(83)	7.7	481	-0.39	-225
2)Western Nagano(84)	6.8	65	0.78	119
3)Northern Nagano(86)	5.9	66	-0.51	25
4)Off Noto(93)	6.6	146	0.12	69
5)Gifu Hida(98)	5.2	32	0.47	73
6)Western Ishikawa(00)	5.8	163	0.06	11
7)Western Tottori(00)	7.3	375	0.04	4
8)Off Tokachi(03)	8.0	842	-0.22	19
9)Off Kii Peninsula(04)	7.4	361	1.68	25
10)Chyuetsu(04)	6.8	173	-0.07	31
12)Off Noto(07)	6.9	108	1.81	216
13)Off Chyuetsu(07)	6.8	173	-0.34	3



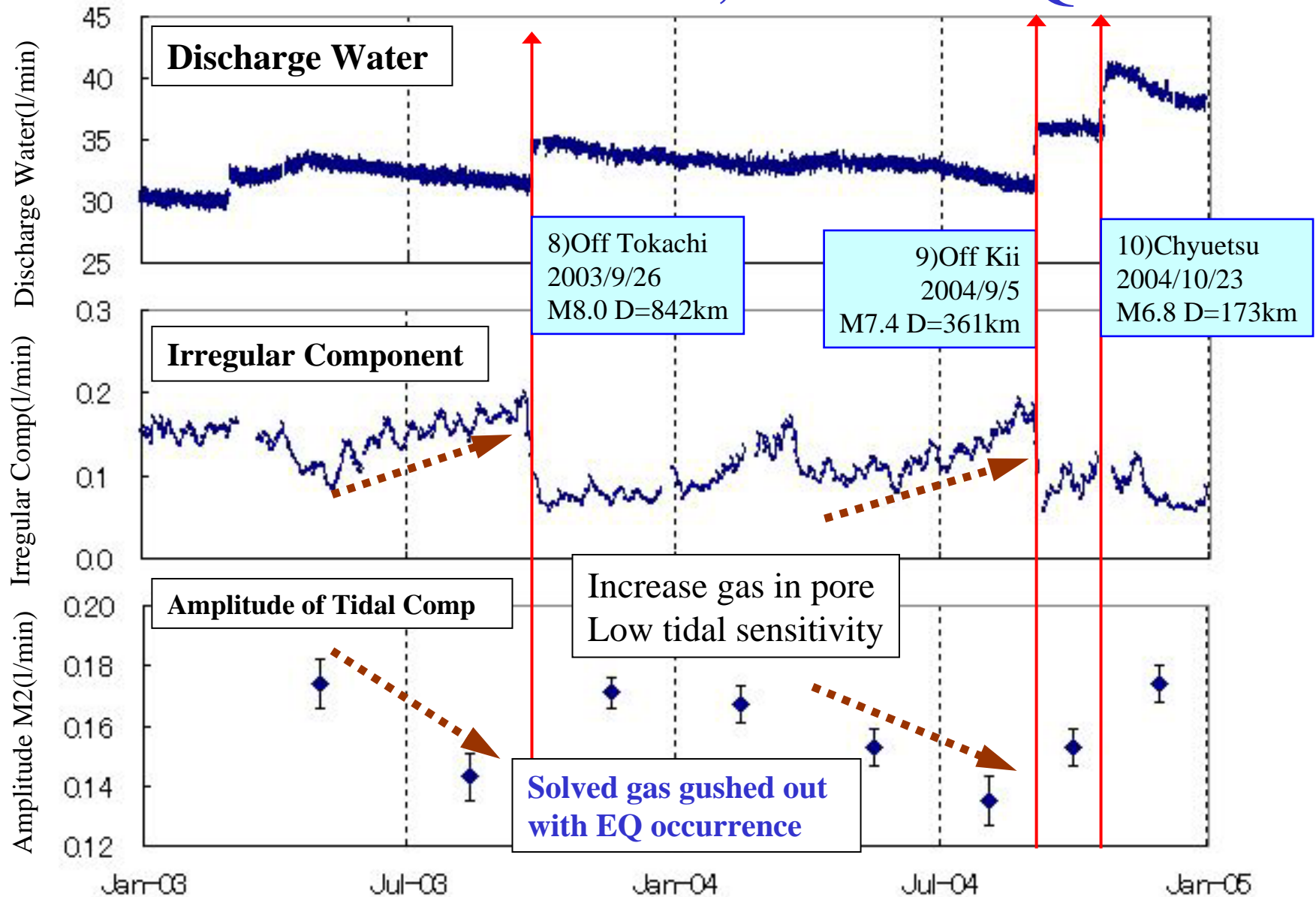
## Model and Observation 10<sup>-8</sup>cubic strain

+:Dilatation -:Compression M:Magnitude, Dist(km)

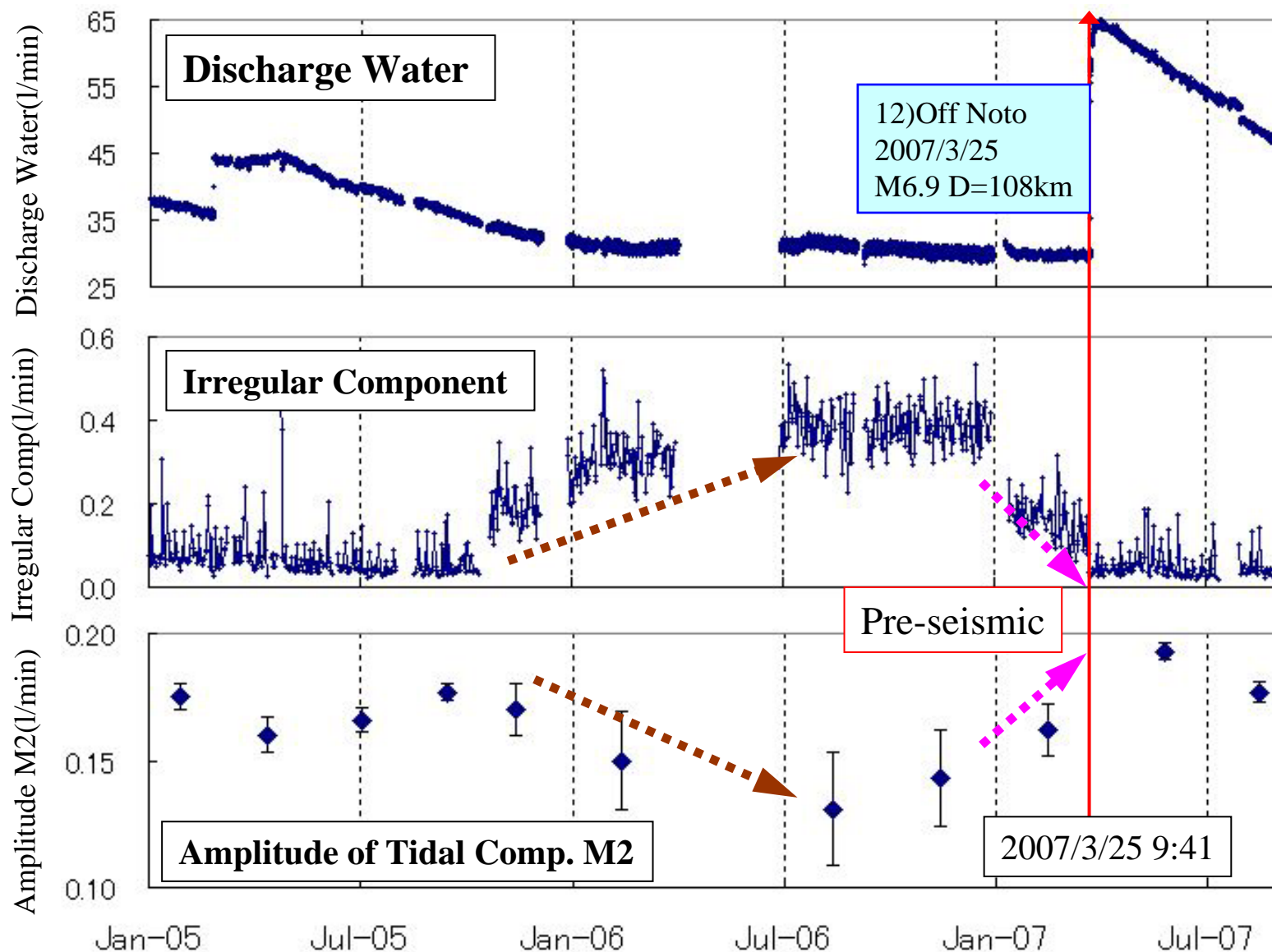
Volumetric Strain was calculated by EQ Fault Model using the MICAP-G Program. Observed Volumetric Strain was calculated from Change of Discharge Water by Tidal Response.

Co-seismic Change of Discharge Water associated with 10EQ were 94 times larger than that expected from EQ Fault Model, without EQ 1) and EQ 9).

# Changes of Irregular Comp. & Tidal Amplitude in Off Tokachi, Off Kii EQ



# Pre-seismic Changes of Irregular Comp. & Tidal Amplitude before Off Noto Earthquake(Mar-25,2007)



# Summary

## 1) Observation of Discharge Water (1977-2007)

Co-seismic changes associated with 13 EQ

Detection limit in Epicentral Distance–Magnitude scatter plots

## 2) Hydro-Seismic Waveform with 1 Hz(2004-2007)

Rayleigh Wave in far three big EQ

Initial P-Waveform in near five EQ with Compression/Dilatation

Unexpected Increase of Discharge Water was observed after arrival of Volumetric Strain or Rayleigh Wave.

## 3) Tidal Response

Sensitivity in Tidal Strain:  $0.16(\text{l/min})/(10^{-8} \text{ volumetric strain})$

Volumetric Strain from Observed Discharge Water are 100 times larger than that from EQ Fault Model.

## 4) Pre-seismic Change in Off Noto Peninsula EQ(Mar-07)

Irregular Component and Tidal Amplitude changed from two months before EQ.