Underground Water Observation in Wari-ishi Hot Spring, Gifu Prefecture

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Introduction

The observation result of underground-water discharge are related to the crustal stress accompanying the earth tide or the occurrence of earthquakes through change of the pore pressure of aquifer layer.

The purpose of this presentation is to clarify the relations of water changes and crust distortion. Analysis of discharge water were performed in the following five viewpoints;

1. Observation site and method
2. Detection of co-seismic changes
3. Earth Tide Analysis
4. Hydro-Seismic Oscillation in 1Hz Sampling Data
5. FFT Analysis of Discharge Water and Local Strain

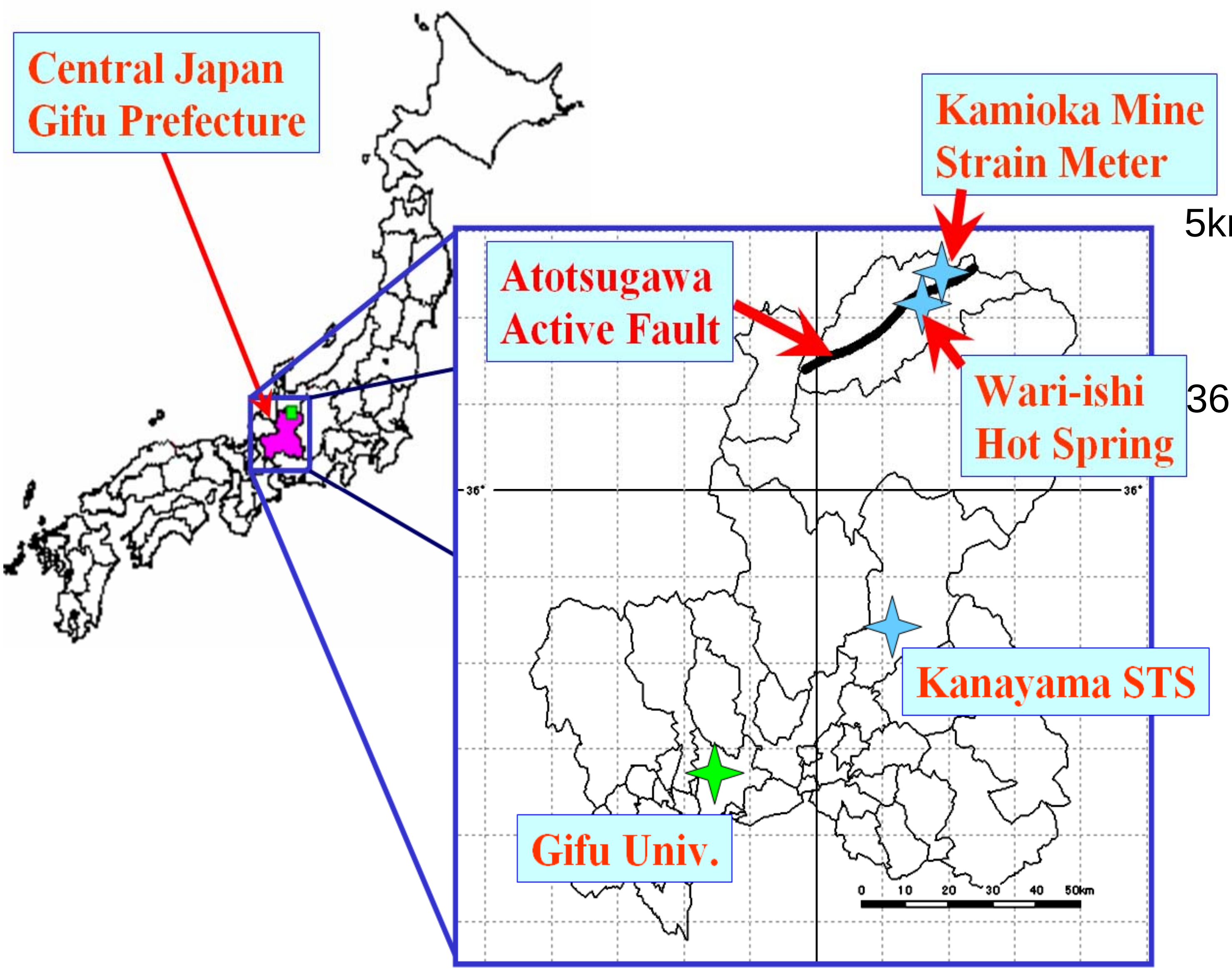
Observation Method

(1)Water Discharge were observed in Wari-ishi Hot Spring by Gifu Univ. and Gifu Pref.

- 1st period:1977-1998 Observed by Bucket and Stopwatch on every Monday
- 2nd period:1998-2003 Electromagnetic Flow Meter in 10 min interval
- 3rd period:2004-2008 Electromagnetic Flow Meter in 1 Hz sampling

(2)Broadband Observation with Laser Strain Meters in KAMIOKA-Mine by Earthquake Research Institute, Univ. of Tokyo

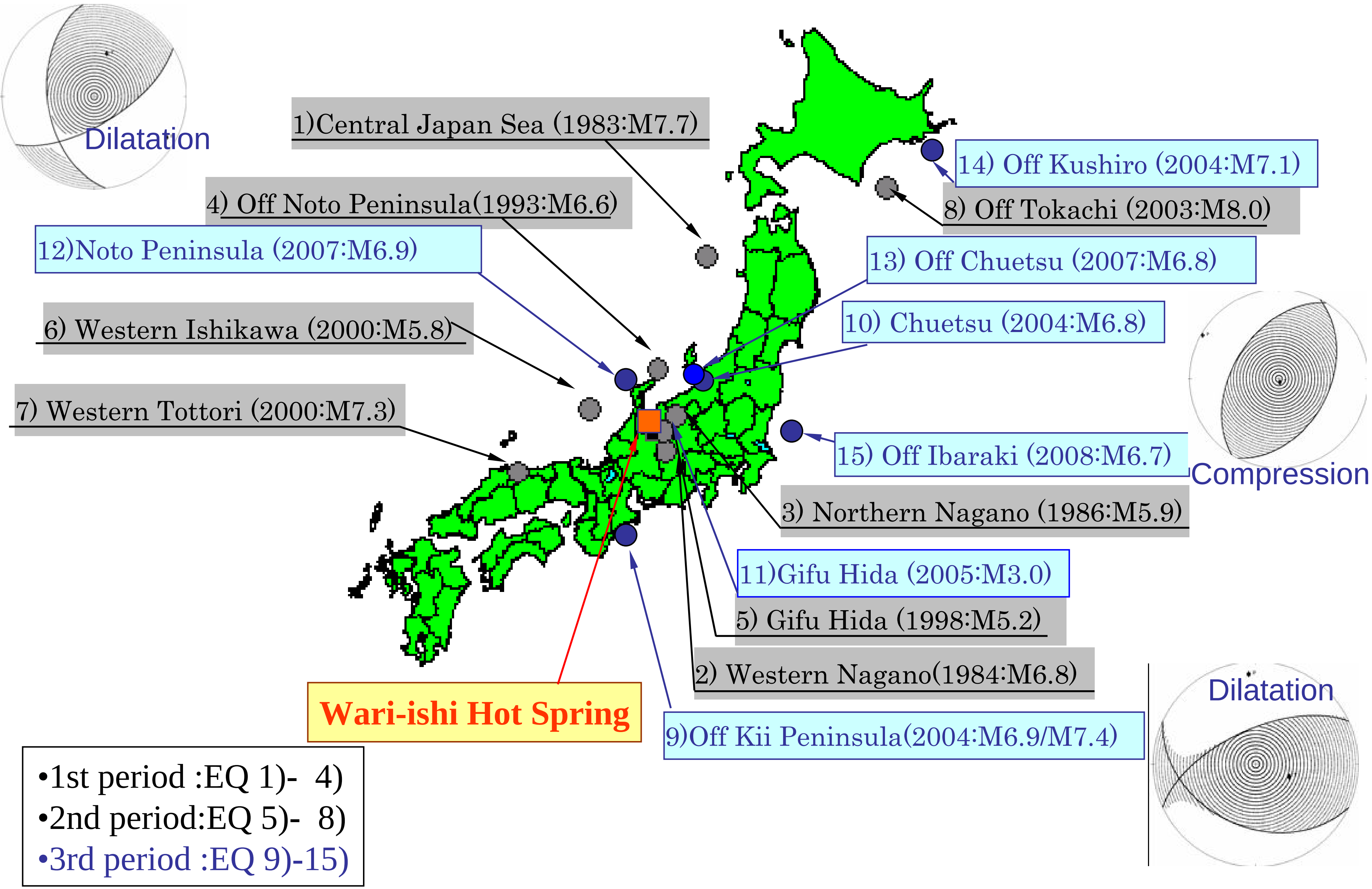
Observation Site Wari-ishi Hot Spring and Kamioka Mine



5km from site

36.3N,137.2E

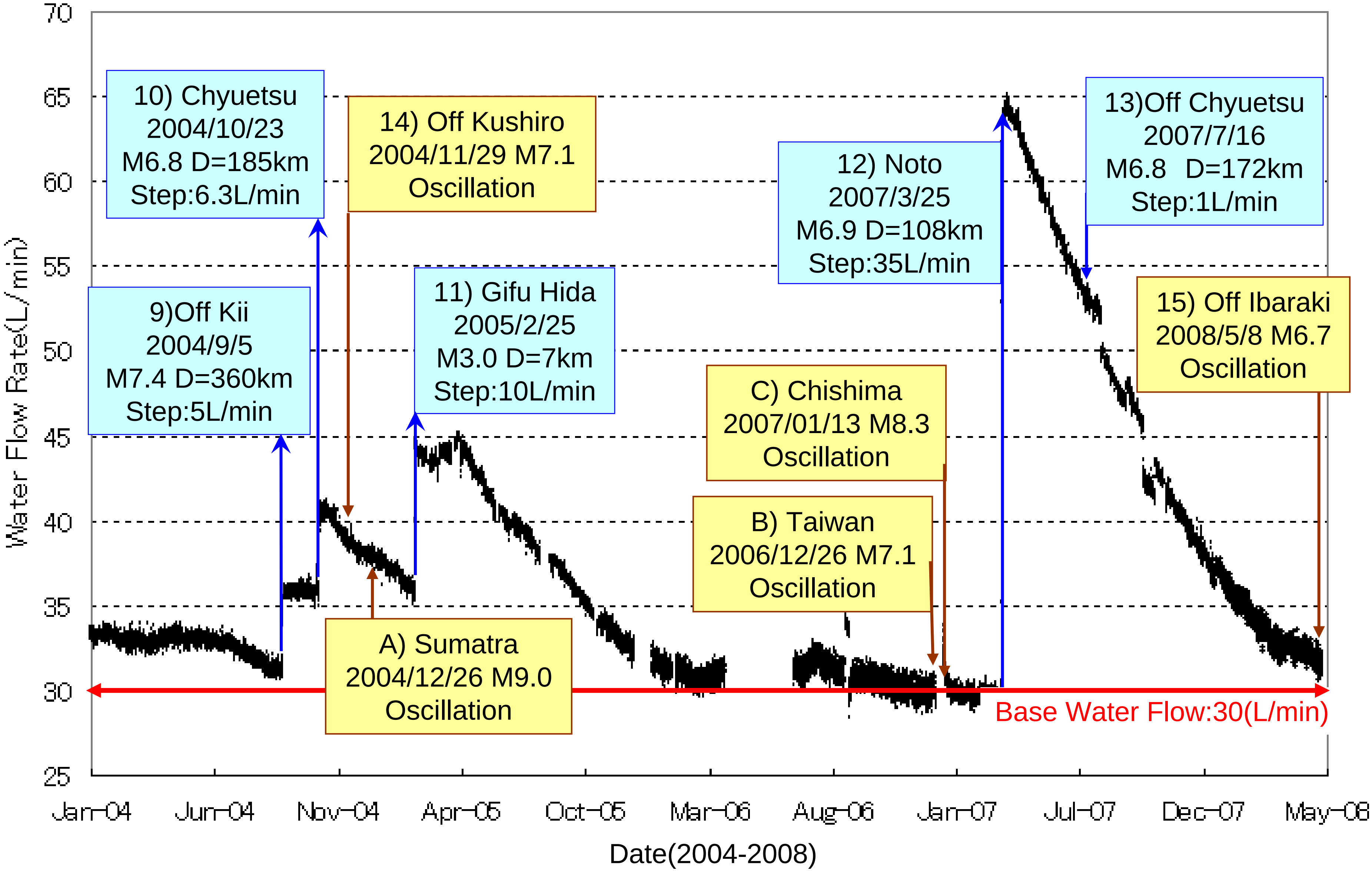
Epicenter Distribution with Co-seismic Changes of Water Discharge (1977-2008)



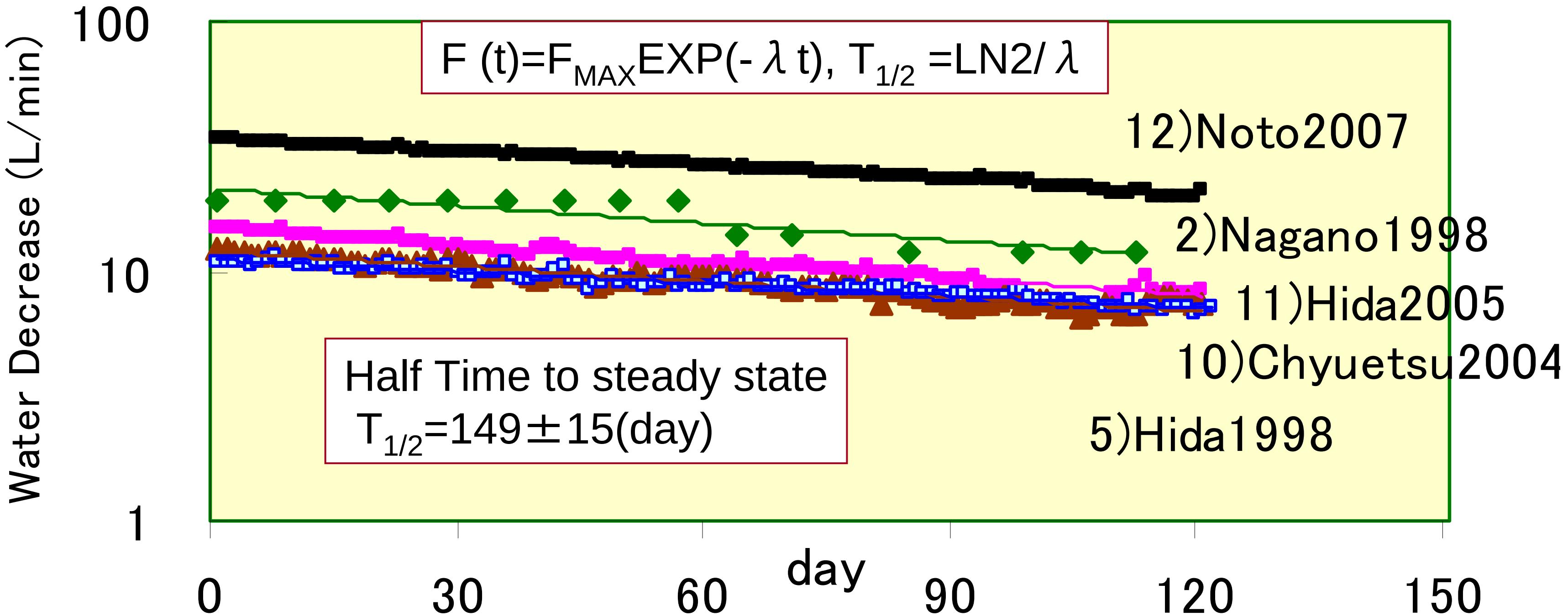
Seismic Changes of Water Discharge in Wari-ishi (1977-2008)

Earthquake	date	Distance (km)	Magnitude	F_{MAX}:Max Water Flow (L/min)
1)Central Japan Sea	1983/05/26	472	7.7	-45.0
2)Western Nagano	1984/09/14	66	6.8	21.4
3)Northern Nagano	1986/12/30	64	5.9	4.0
4)Off Noto Peninsula	1993/02/07	145	6.6	20.0

Time variations of Water Discharge (3rd period:2004-2008)



Attenuation Curve to steady state after 5 EQ



Earthquake (with Step)	F_{MAX}(L/min) Max Water Flow	$T_{1/2}$(day)
2) Nagano 1984(M6.8)	21.4	131
5) Hida 1998(M5.4)	12.0	151
10) Chyuetsu 2004(M6.8) (added to Kii)	11.3	165
11) Hida 2005(M3.2)	14.7	138
12) Noto 2007(M6.9)	34.1	162

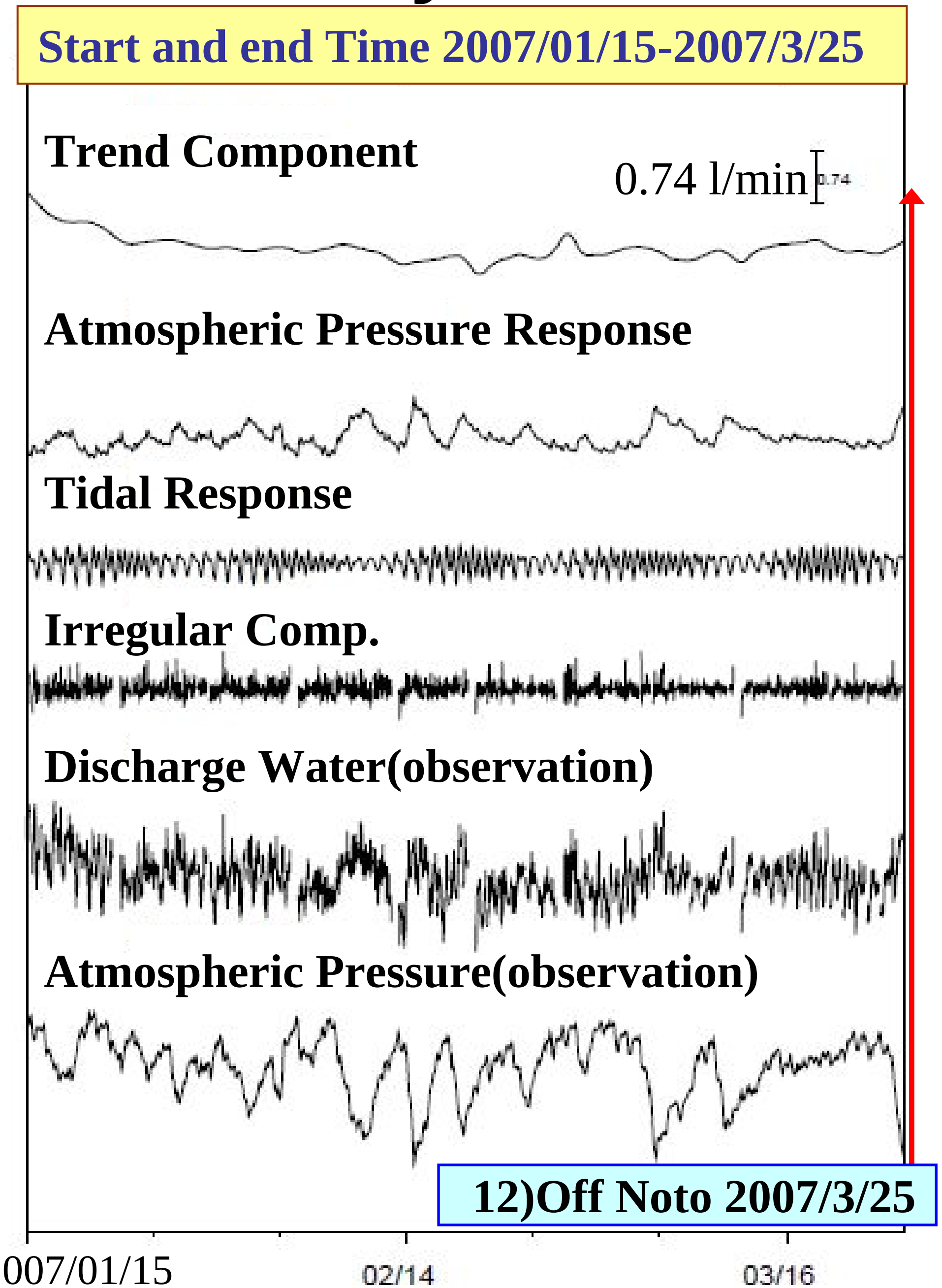
Tidal Response Analysis

Flow Rate/Discharge Water
Atmospheric Pressure

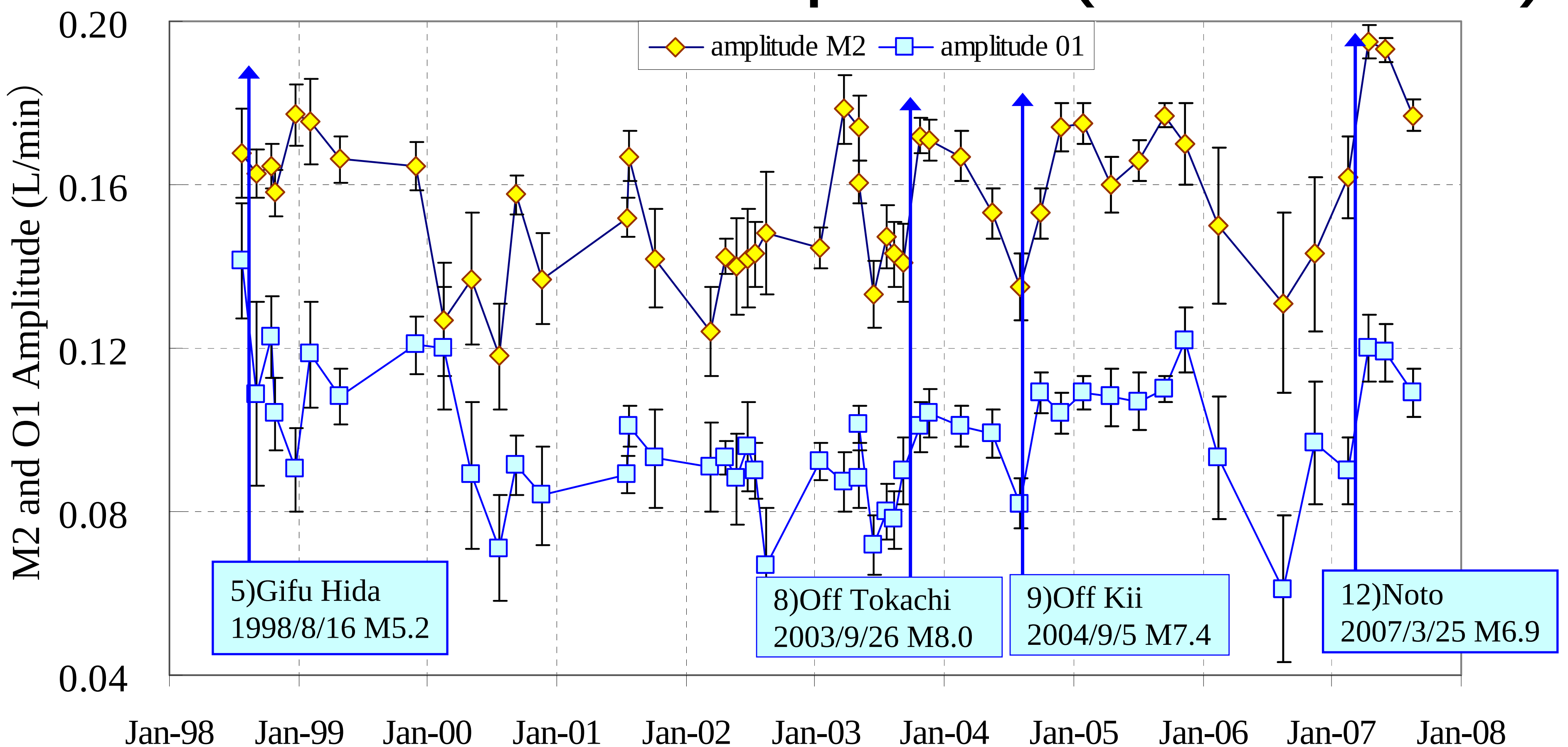
BAYTAP-G
Tidal Response
Atmospheric Response

- Trend component
- **Irregular component**

- Tidal Amplitude
- **Solved Gas**



Tidal O1 and M2 Amplitude(1998-2007)



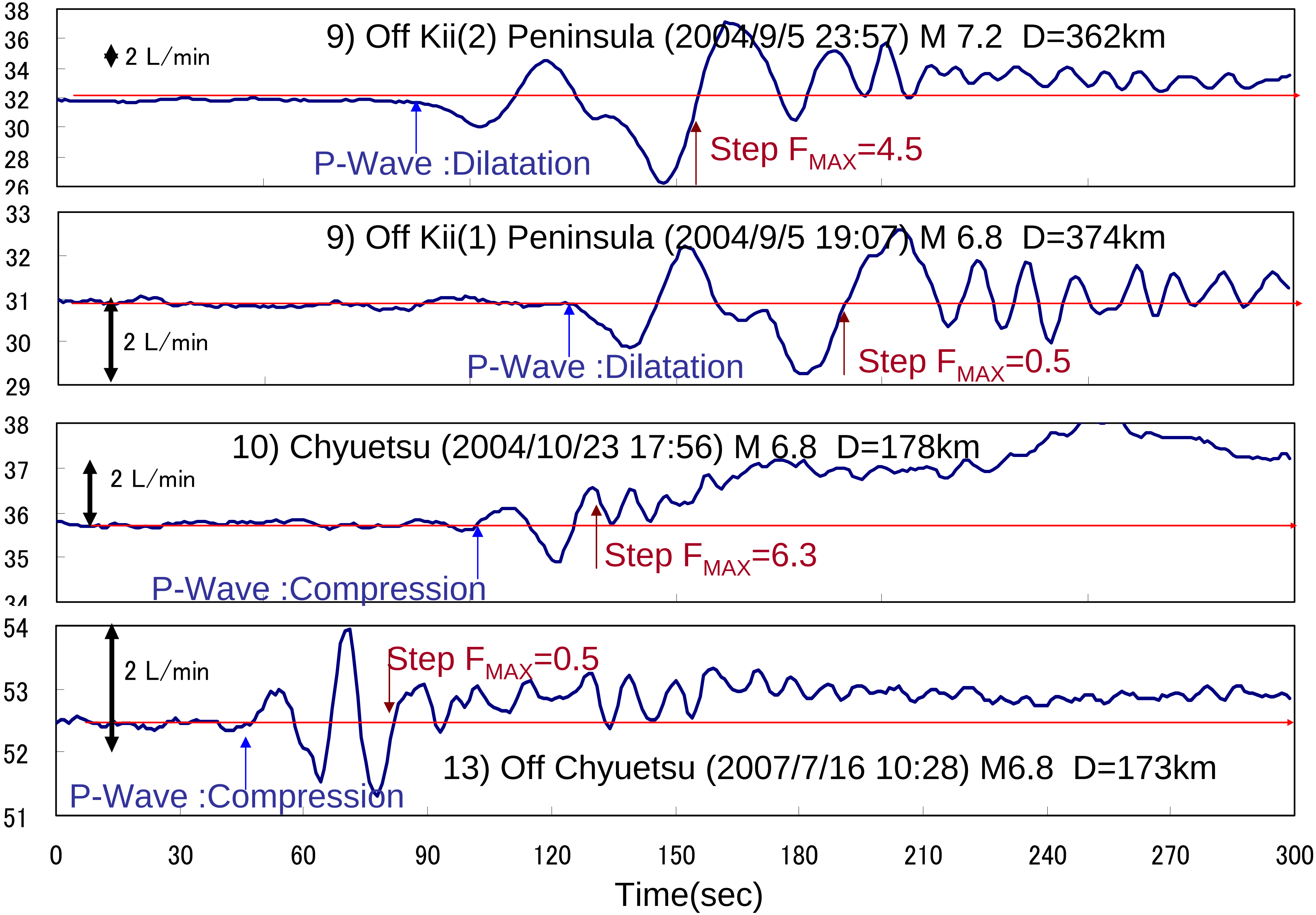
Tidal Amplitude of Discharge Water in Wari-ishi

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

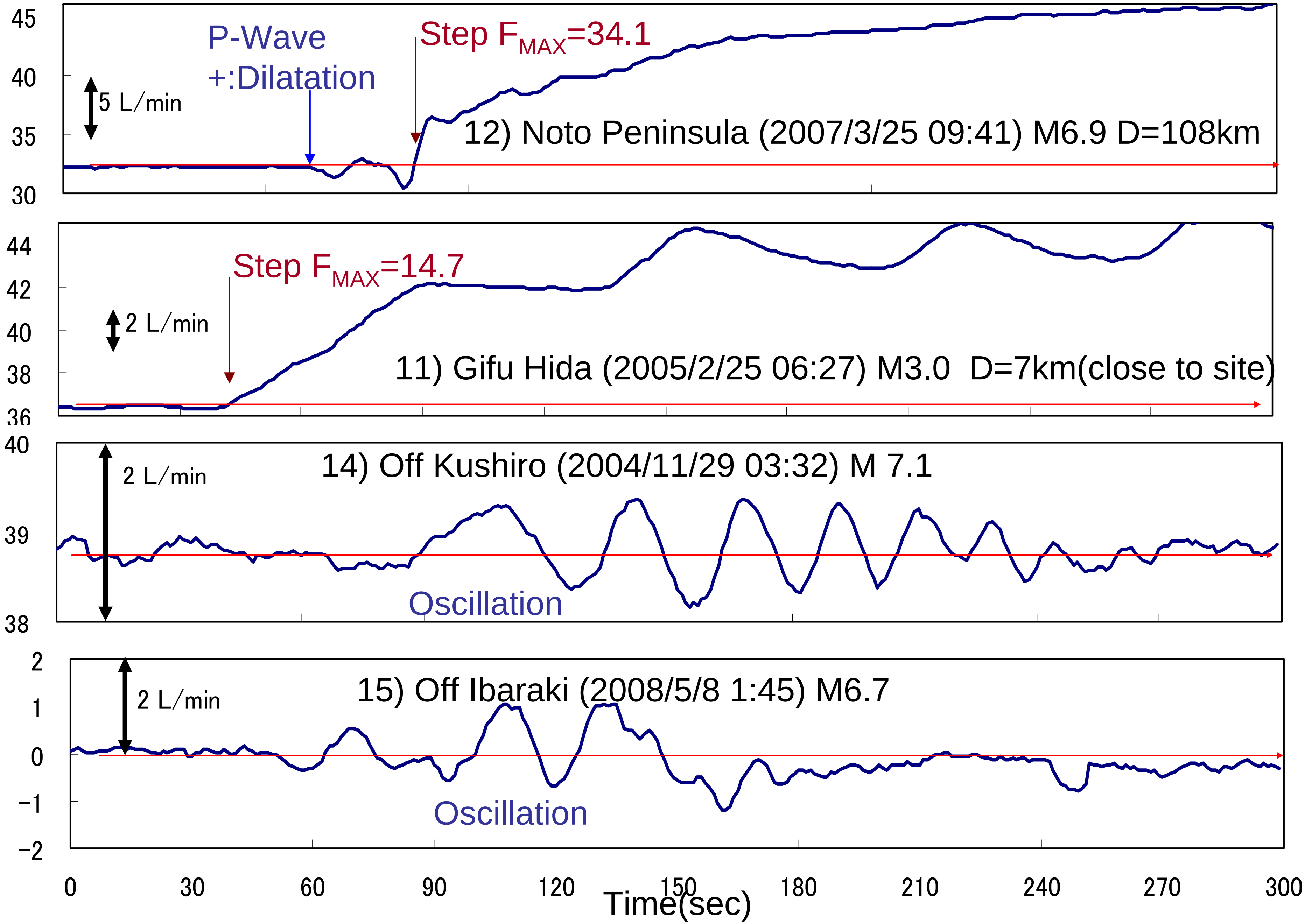
Tidal Strain Calculated by GOTIC2 M2:0.997, O1:0.671(10^{-8} cubic strain)

Sensitivity of Discharge Water **M2:0.16, O1:0.15(L/min)/(10^{-8} cubic strain)**

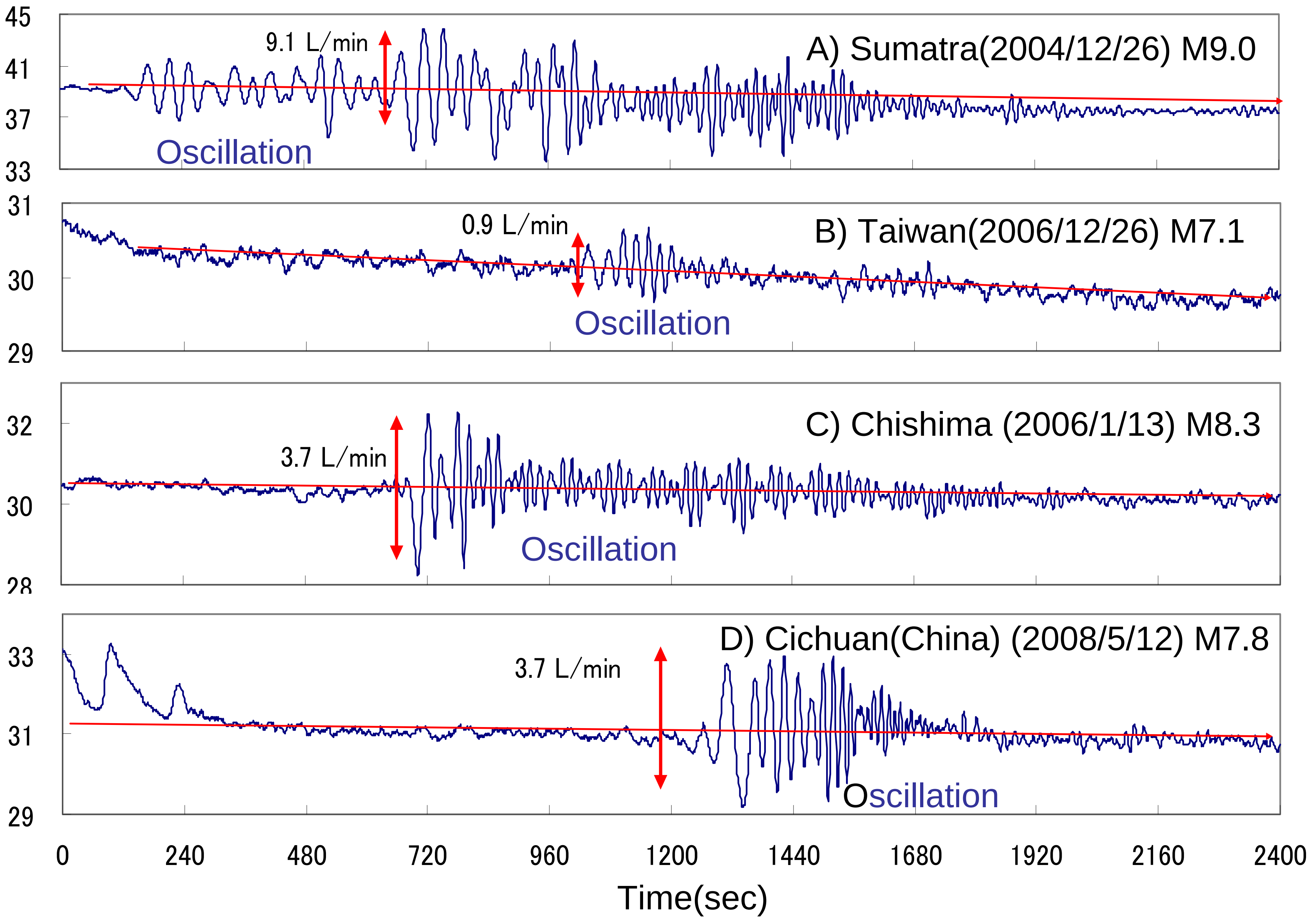
Hydro-seismic waveform with step-like increase



Hydro-seismic Waveforms step-like increase and Oscillation



Hydro-seismic Waveforms of Far Big Earthquakes



FFT Analysis of Discharge Water and Area strain

KII Earthquake(2)（2004/9/5 M7.4）

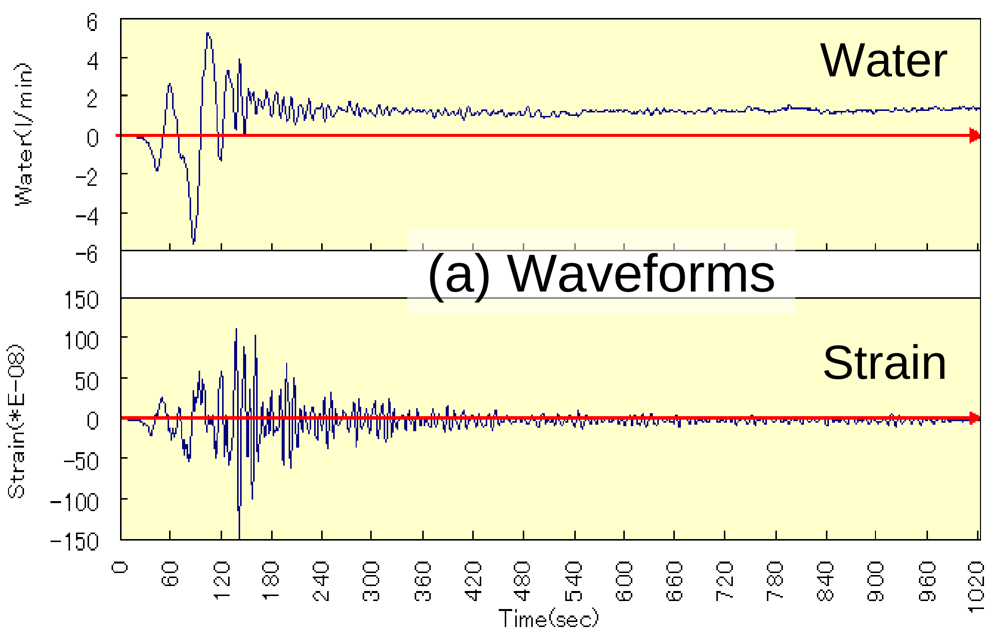
with step-like increase

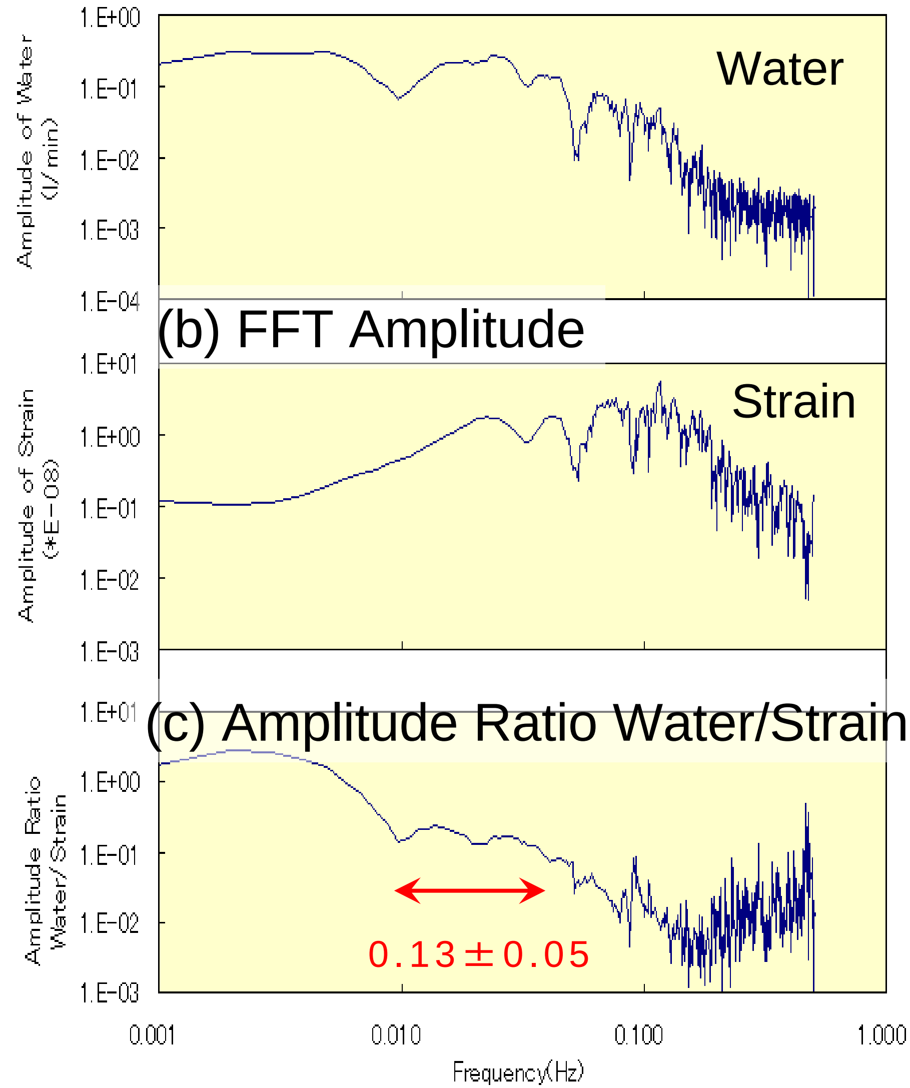
F_{Max}=3.5(L/min)

Frequency Region: 10-50mHz

Amplitude Ratio (Water/Strain)

0.13±0.05(L/min)/(10^{-8}strain)

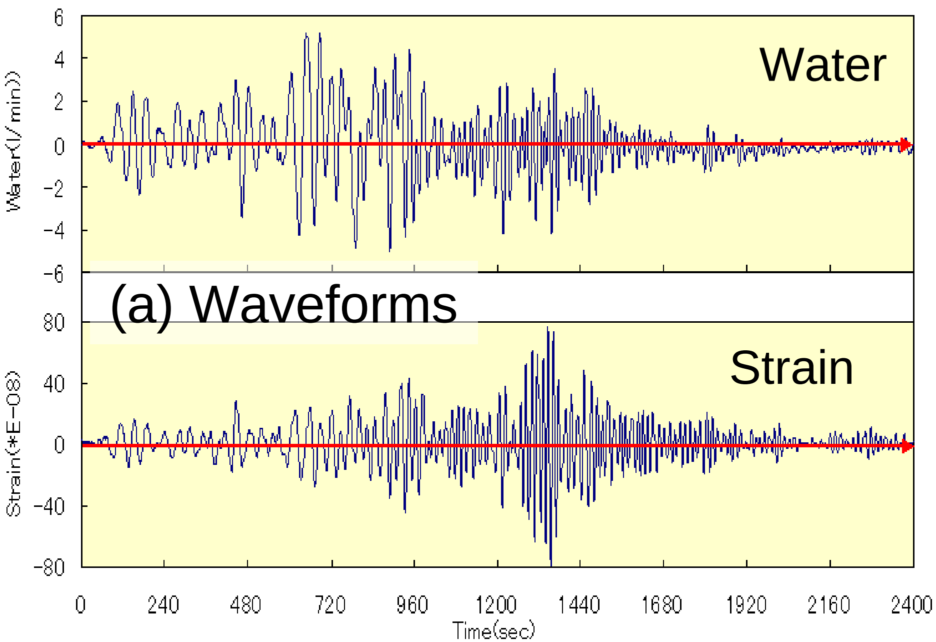


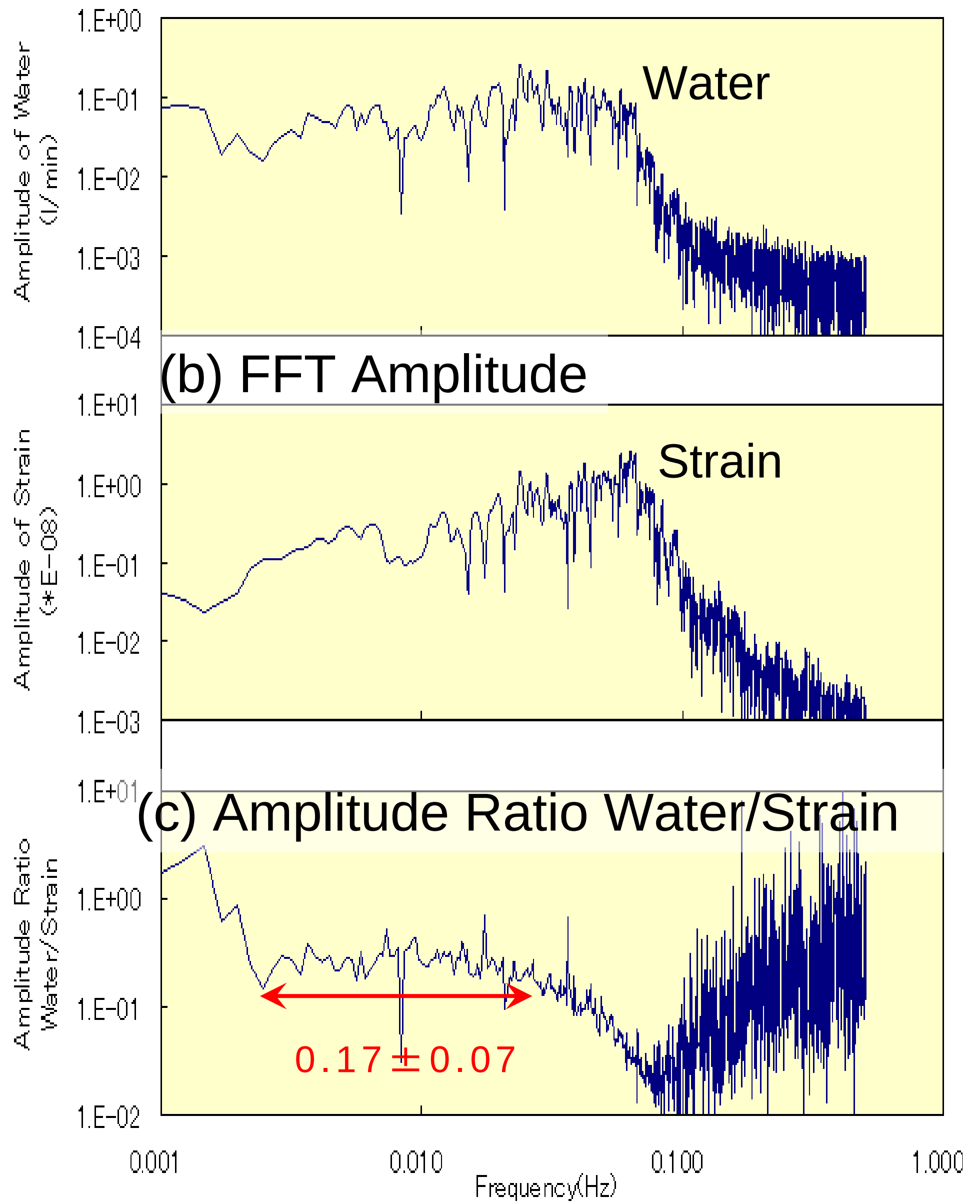


FFT Analysis of Discharge Water and Area strain

Sumatra Earthquake
（2004/12/26 M9.3）
without step increase

Frequency Region: 3-50mHz
Amplitude Ratio (Water/Strain)
0.17±0.07(L/min)/(10^{-8}strain)





Summary

(1) Seismic Change of Water Discharge in Wari-ishi 19 Earthquakes (1977-2008)

(2) Attenuation Curve to steady state after 5 Earthquake

$F(t)=F_{MAX}EXP(-\lambda t)$, $T_{1/2}=149\pm15$(day)

(3) Tidal Analysis of O1 and M2 Amplitude(1998-2007)

O1(25.8h)：0.16

M2（12.4h）：0.15 (L/min)/(10^{-8} strain)

(4) Initial water change (Dilatation/Compression) consistent with the Focal Mechanism Solution of Earthquake.

(5) FFT Analysis of Discharge Water and Area Strain

Region of Frequency 3mHz-50mHz

Kii Peninsula EQ (1) (2) ： 0.13 ± 0.05

Sumatra EQ：0.17 ± 0.07 (L/min)/(10^{-8} strain)