Developing a Prototype System for Earthquake Early Warning Using tau_c Method

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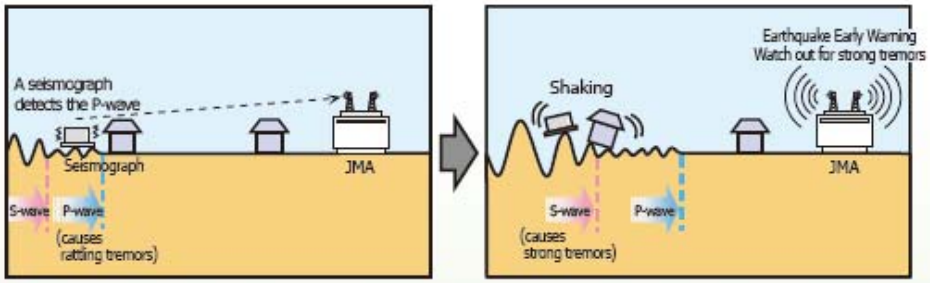
Earthquake Early Warning

or "緊急地震速報 (Kinkyu Jishin Sokuho)" in Japanese

A New Advance Earthquake Alert

Starting 1 October 2007

As of 1 October 2007, the Japan Meteorological Agency (JMA) will start the Earthquake Early Warning, a new service that advises of strong tremors before they arrive.



- The Earthquake Early Warning system automatically calculates the focus and magnitude of the earthquake and estimates the seismic intensity for each location by detecting the quake (i.e. the P-wave, or the preliminary tremor) near its focus. An Earthquake Early Warning is then given a matter of seconds (i.e. a few seconds to a few tens of seconds) before the arrival of strong tremors (i.e. the S-wave, or principal motion).
- Earthquake Early Warnings will be provided through various media outlets such as TV and radio.
- Please note that strong tremors may arrive at the same time as the Earthquake Early Warning in areas that are close to the focus of the earthquake.

2007
Japan Meteorological Agency
Ministry of Land, Infrastructure and Transport

http://www.jma.go.jp/jma/en/Activities/eew.html

Earthquakes issued EEW

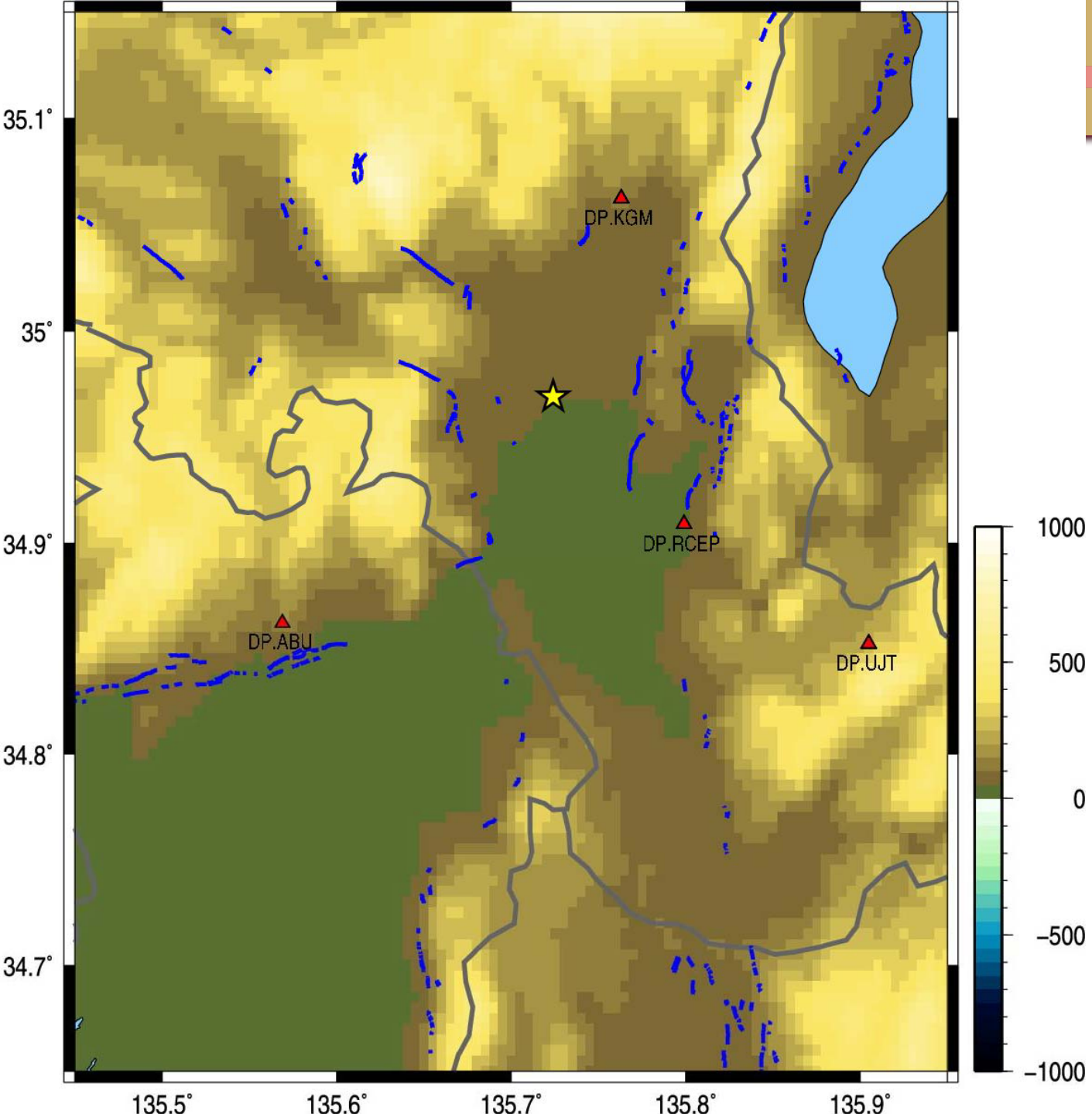
1. 2008/4/28 Miyakojima-oki
   11 seconds (too large estimate)
2. 2008/5/8 Ibaragiken-oki
   58 seconds
3. 2008/6/14 Iwate-Miyagi Inland
   5 seconds
4. 2008/6/14 Iwate-Miyagi aftershock
   8 seconds
5. 2008/7/8 Okinawa-honto-oki
   14 seconds
6. 2008/7/24 Northern Iwate
   21seconds
7. 2008/9/11 Tokachi-oki
   10 seconds

10-20sec to issue a warning

Summary

- Local seismic network
  - Install broadband seismometers in Kyoto
- Empirical relationship of magnitude and tau_c
  - Estimate magnitude from tau_c and Pd
- Develop a prototype system
  - Regional warning
  - Onsite warning (near-field term warning)

Stations

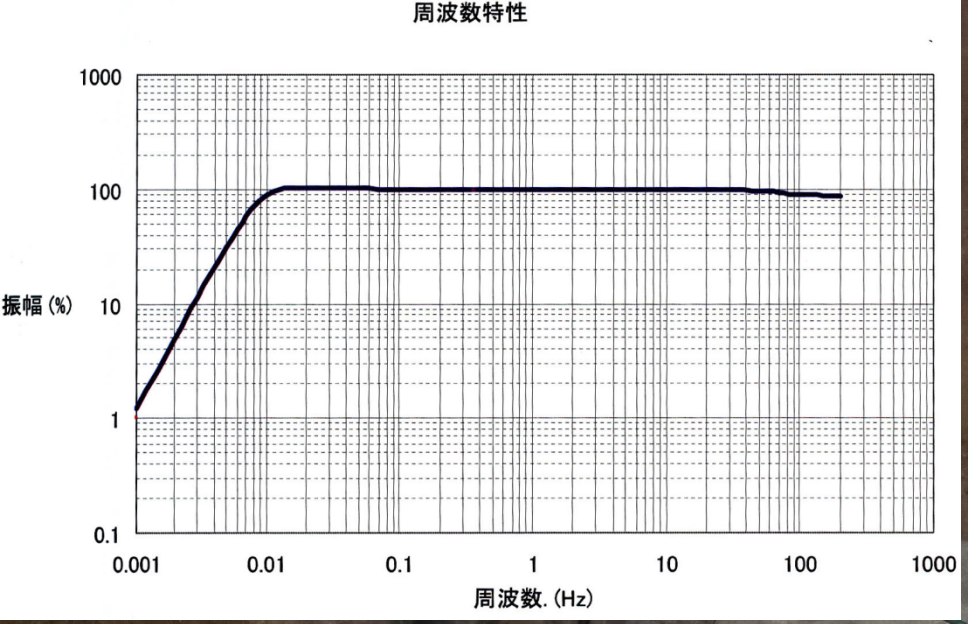

35.1°
35°
34.9°
34.8°
34.7°
135.5°
135.6°
135.7°
135.8°
135.9°
DP.KGM
DP.RCEP
DP.ABU
DP.UJT
1000
500
0
−500
−1000

ABUYAMA

KAMIGAMO

UJITAWARA

DPRI
京都大学
KYOTO UNIVERSITY

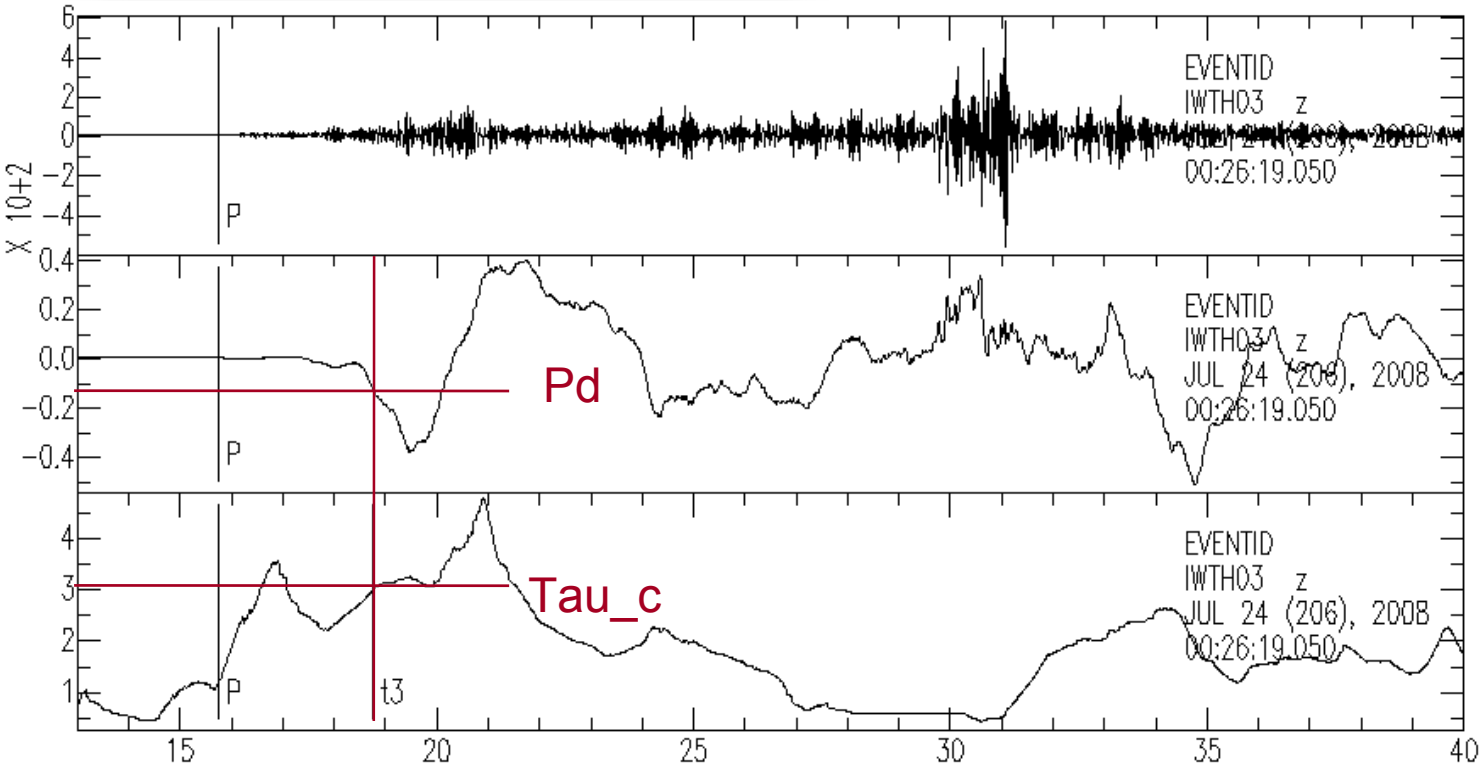


VSE-355G3
Strong Motion Seismometer

Tau_c Method

$$\tau_c = 2\pi \sqrt{\frac{\int_0^{\tau_0} u^2(t)dt}{\int_0^{\tau_0} \dot{u}^2(t)dt}}, \qquad (1)$$

Tau_c Method:
Estimate magnitude from the P-wave period parameter



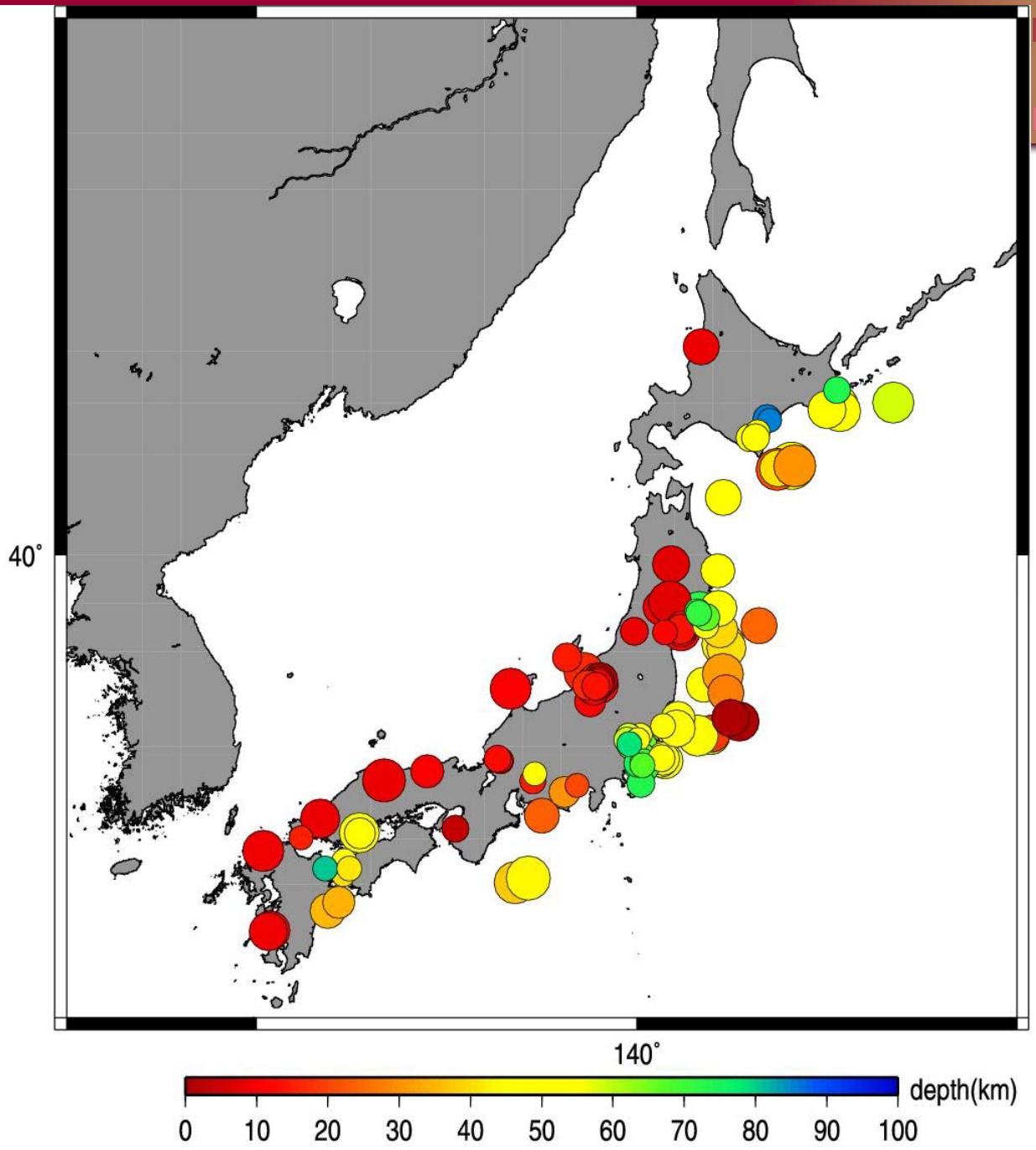
Acceleration

Displacement

Tau_c

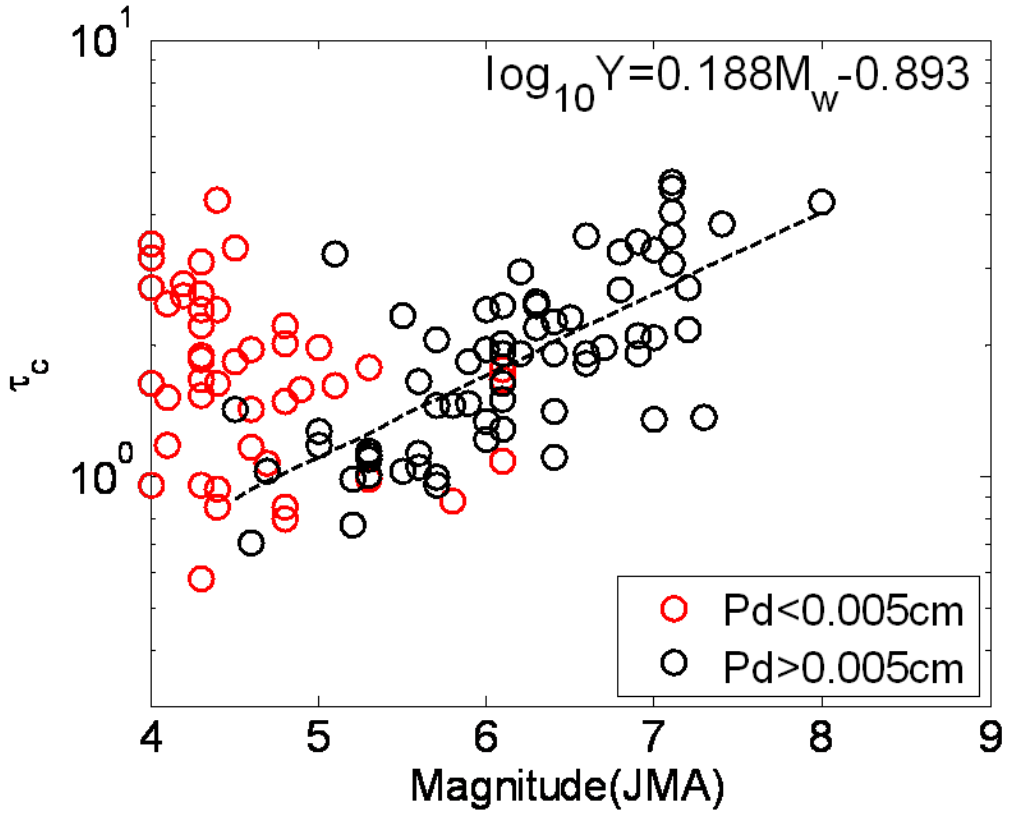
Kanamori, 2005

Dataset



118 events
4 < Mjma < 8
from 1996 to 2008
K-NET and KiK-net
records

Magnitude estimate from Tau_c

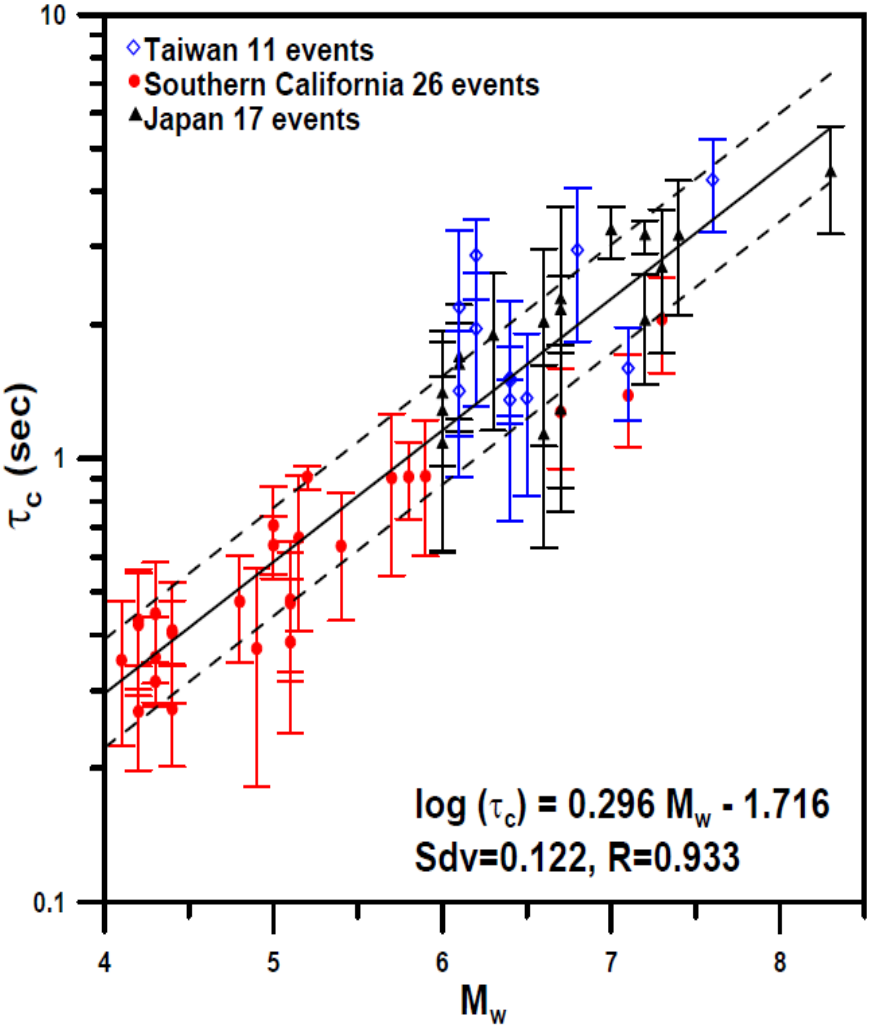


$\log_{10}(\text{tau_c}) = 0.188\ \text{Mw} - 0.893$ (Japan)

Poor S/N ratio for small earthquake.

Magnitude estimate from Tau_c

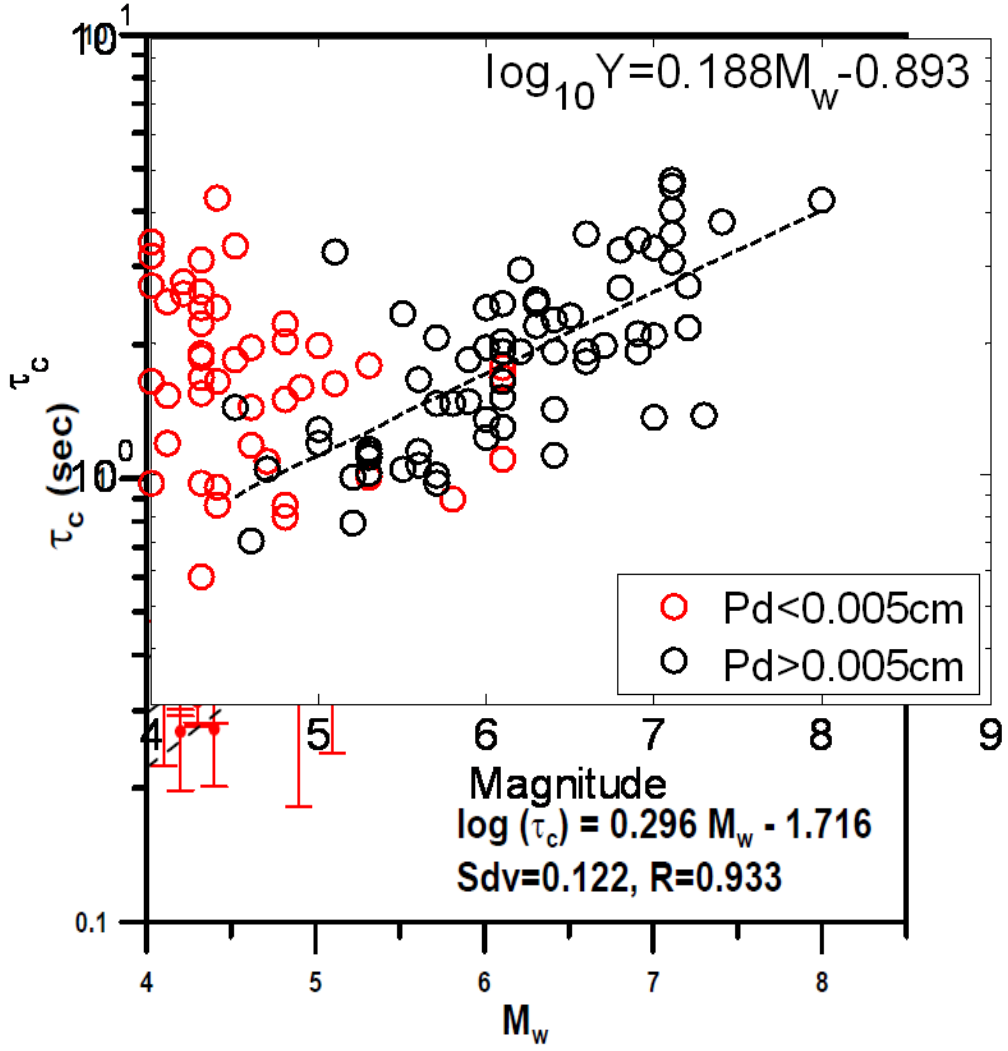
(Wu and Kanamori 2008)



$\log_{10}$ (tau_c) = 0.296 Mw −1.462 (Taiwan, CA, and JPN)

Magnitude estimate from Tau_c

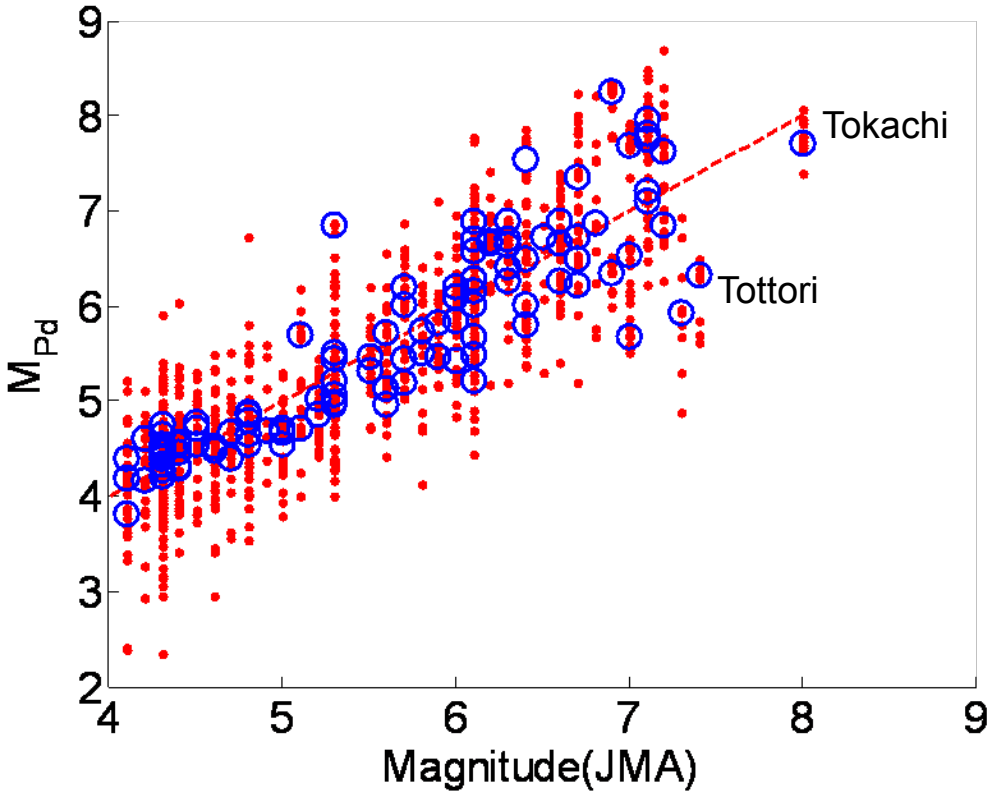
(Wu and Kanamori 2008)



Different slope (JMA Magnitude, uncertainty of large EQ)

Magnitude estimate from Pd

(Wu and Zhao 2006)



R < 30km or
closest 10 station

$M_{Pd} = 5.164 + 1.652 \log_{10}(Pd) + 1.715 \log_{10}(R)$ (Japan)

$M_{Pd} = 4.748 + 1.371 \log_{10}(Pd) + 1.883 \log_{10}(R)$ (California)

Real-time Waveform

SHMX version 1.15

8051 + - 5 Level 2
9051 + - 2 Level 3
8048 + - 5 Level 3
9048 + - 2 Level 4

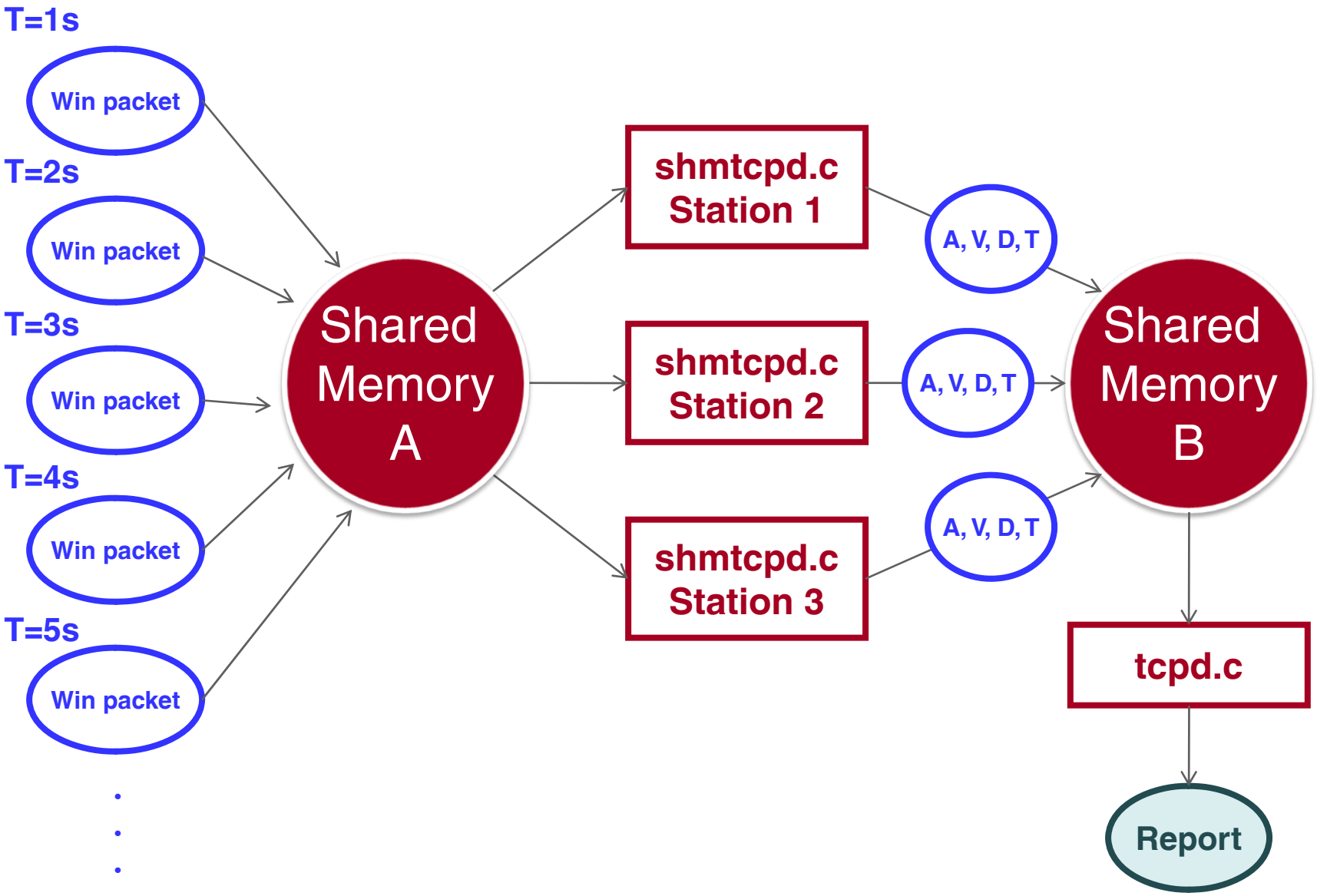
02:28
02:29
02:30
02:27

DP.KGM AU
30:59
--- --
30:59
DP.ABU AU
30:59
--- --
30:59
DP.UJT AU
30:59
--- --

MIN: 1 LTA: 30 LSB +/-: 12.0 PIXEL +/-: 12 08/09/07 02:30:59 QUIT

EEW Display

Flow chart of the data transmission



EEW Report

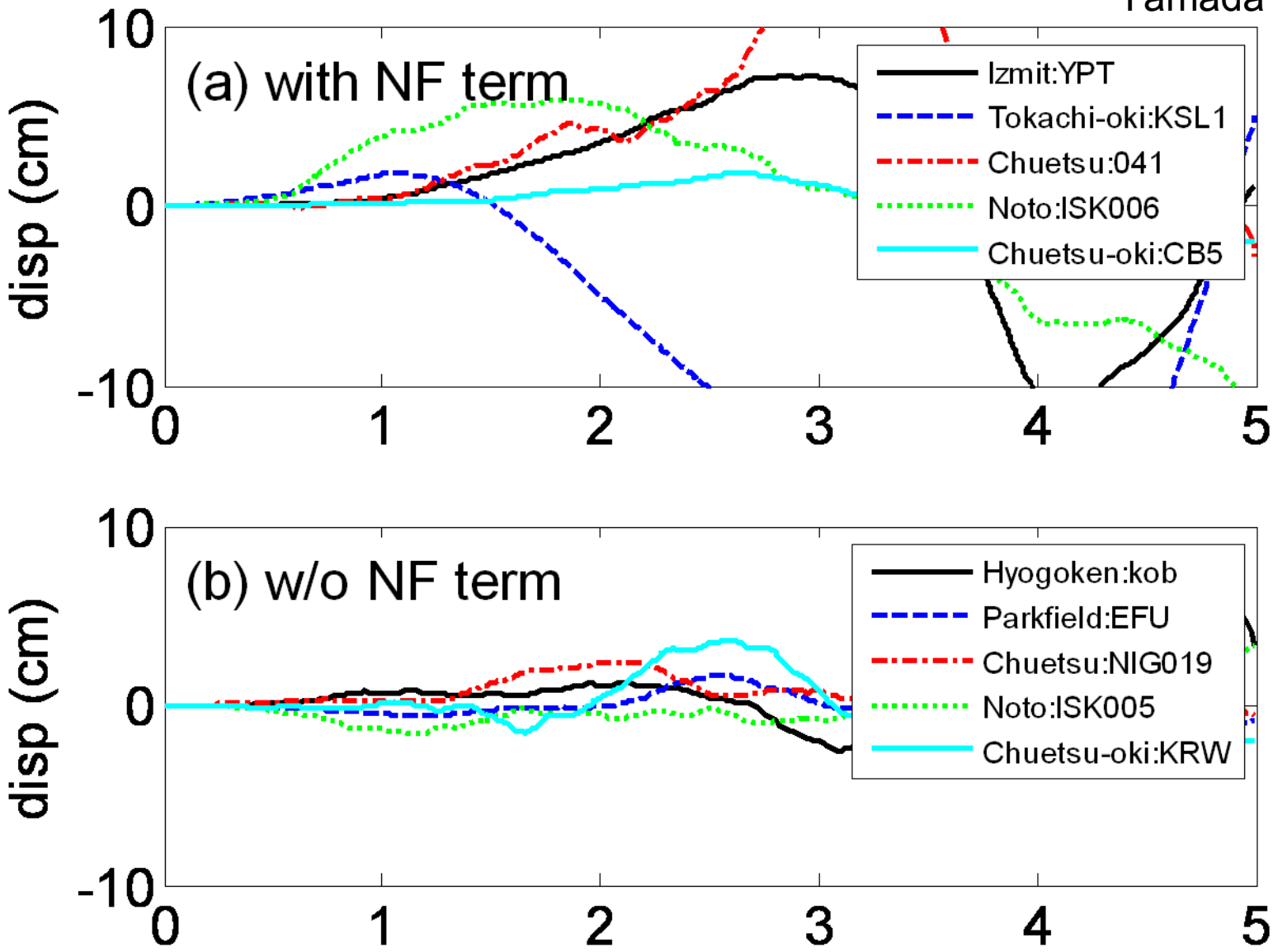
Cygwin Bash Shell

```
First_P-arrive_time     2009/02/08,22:17:40.845
Reporting_time          2009/02/08,22:17:48.839
Centroid_Latitude        23.61927
Centroid_Longitude       120.59933
Centroid_Mtc              6.62
Predicted_averaged_PGV      21.698
Event_origin_time       2009/02/08,22:17:38.873
Epicenter_Latitude       23.61458
Epicenter_Longitude      120.83288
Epicenter_Depth(km)      11.94
Mpd                      6.55
Revised_Mtc              6.71
Average_traveltime_residuals    0.474
Revised_predicted_averaged_PGV     30.480

stnID   stla    stlo    Parrival_time          Tc(s)  Pd(cm)  Pv(kine) report_time  delay trav_res
C074    23.510  120.805 2009/02/08,22:17:40.84 3.105   2.7567   5.3300 22:17:44.39   3.542 -0.2736
C028    23.632  120.605 2009/02/08,22:17:42.77 1.162   0.0888   0.8463 22:17:46.00   3.225 -0.1869
C030    23.644  120.475 2009/02/08,22:17:43.54 1.400   0.1200   0.5026 22:17:47.89   4.342 -1.7328
C035    23.520  120.584 2009/02/08,22:17:43.82 1.032   0.0703   0.4291 22:17:47.06   3.242  0.1115
C024    23.757  120.606 2009/02/08,22:17:43.83 2.326   0.2018   0.6969 22:17:47.59   3.759  0.0357
C101    23.686  120.562 2009/02/08,22:17:44.01 1.309   0.1585   1.0803 22:17:48.09   4.077  0.1037
C036    23.607  120.479 2009/02/08,22:17:45.41 2.771   0.2009   0.6991 22:17:48.79   3.374  0.2195
```

Near-field term of large earthquakes

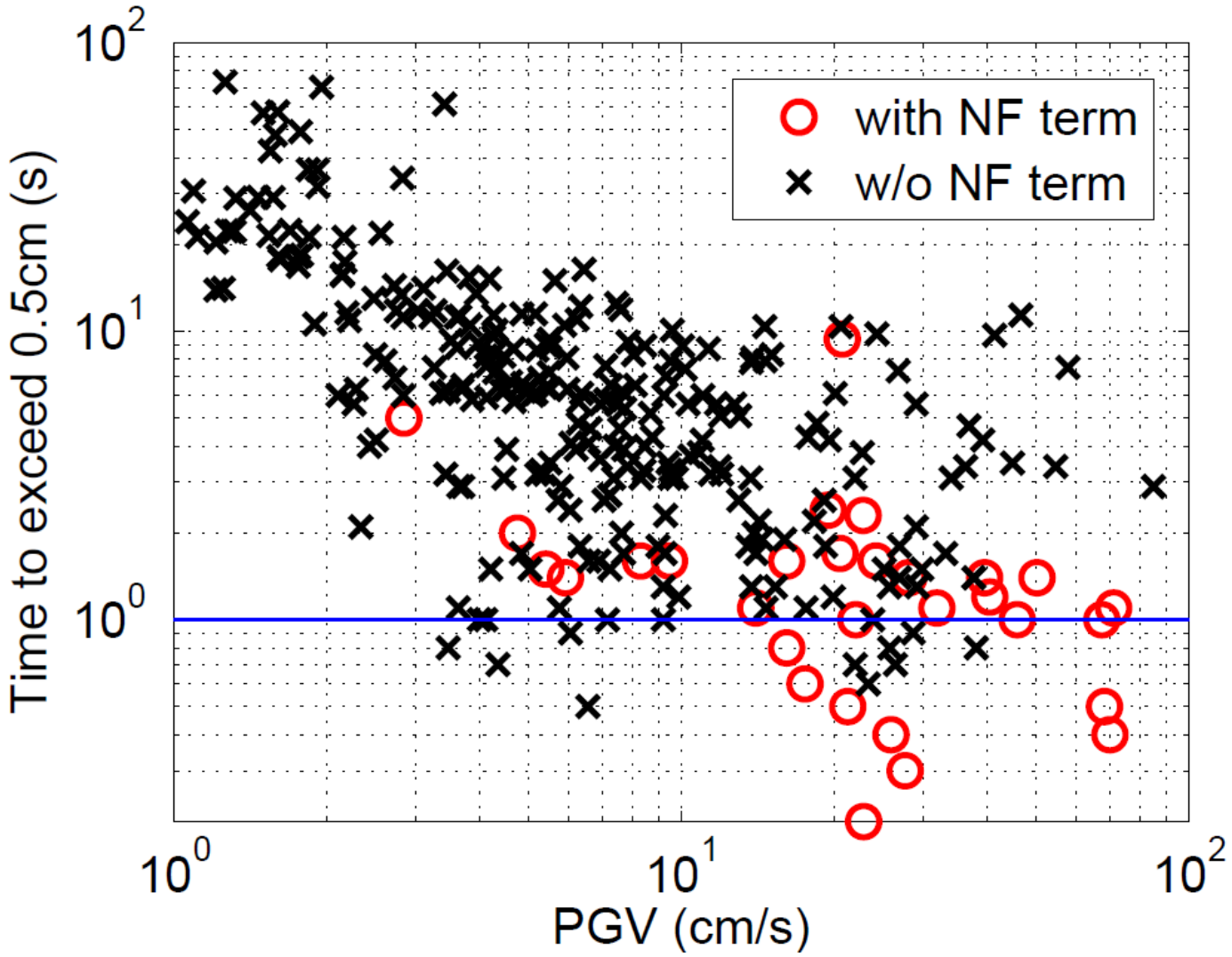
Yamada and Mori, 2008



Large & clear NF term

Small & unclear NF term

PGV and Time when Pd>0.5cm



Warning: if the displacement exceeds 0.5cm

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