Development of earthquake early warning and shakemaps system using low cost sensors in Taiwan

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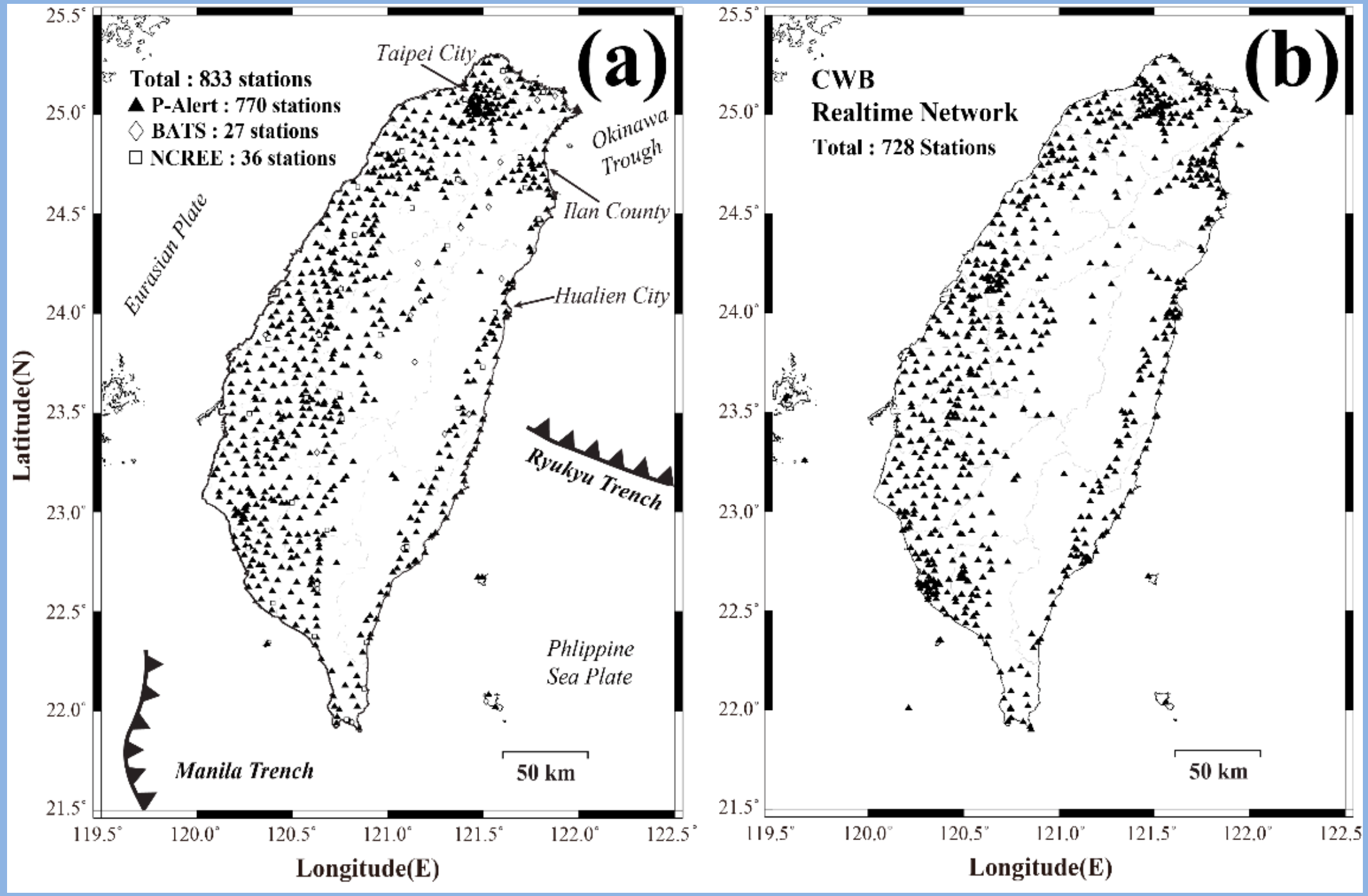
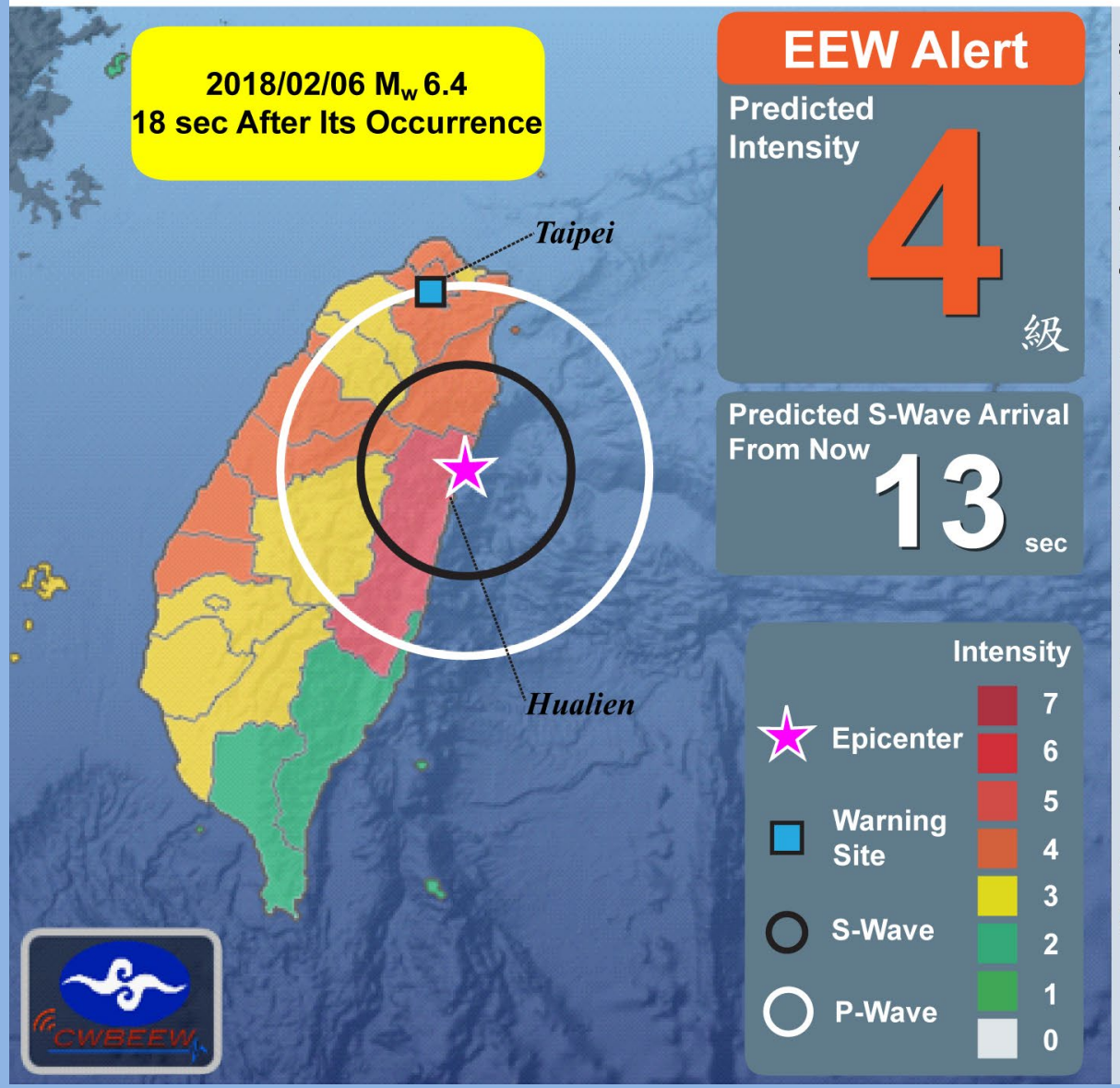
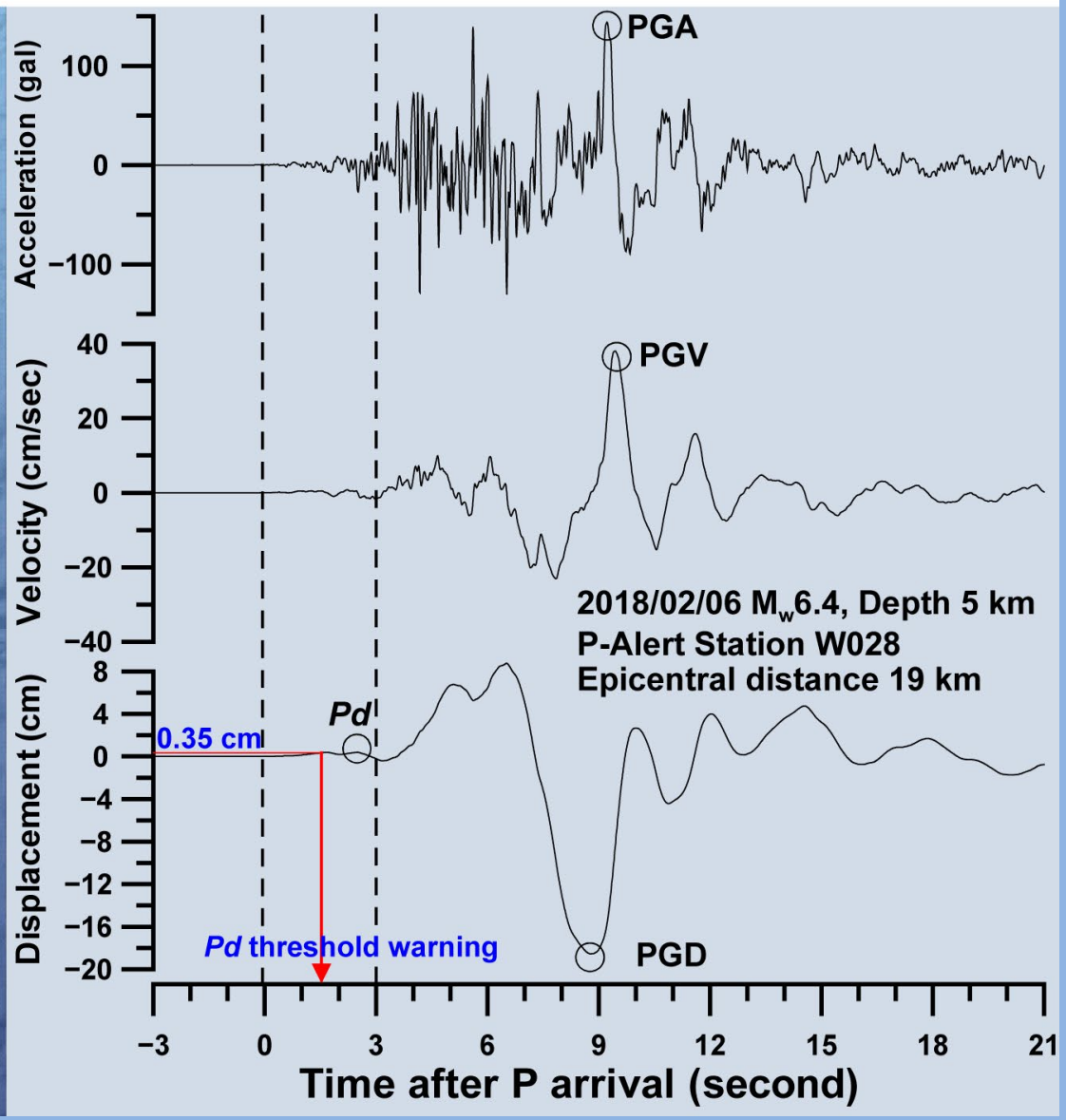

(a)
Total : 833 stations
▲ P-Alert : 770 stations
◇ BATS : 27 stations
□ NCREE : 36 stations
Taipei City
Okinawa Trough
Ilan County
Hualien City
Eurasian Plate
Ryukyu Trench
Phlippine Sea Plate
Manila Trench
50 km
Latitude(N)
Longitude(E)
(b)
CWB
Realtime Network
Total : 728 Stations
50 km
Longitude(E)

Regional Warning v.s. On-site Warning





Combination with modern MEMS sensor. Cheaper device may install to every building to give warning within three seconds after P arrival after a large earthquake occurs.

全部 好友 群組 官方帳號

搜尋聊天和訊息

CYHsieh傳送了影片

A.M.M.Huda 上午 7:42
Thank you Professor.

海量前瞻科技研... (17) 上午 6:28
CYHsieh傳送了影片

春宴 (15) 昨天
阿呀！ 接小孩下課！ 錯失見貓院士的機會

Wei-Sen Li (維森) 昨天
收到

國家災害防救科技中心 昨天
國家災害防救科技中心-全球災害事件典藏分析!!

左秀靈 星期三
本歌的背景及女主角，喜歡戶外攝影者，請仔細看。得金項...

NTU CUBE EEW (8) 星期三
【三聯科技地震訊息服務】地震報告 CWB 2022-11-09_15:4...

海洋學系 (7) 星期三
舉頭望明月 低頭思故鄉

好酒輕鬆喝 星期二
¥New/博特酒莊 昇華 精裝風乾酒, 美型登場！

Simon Lee 星期二
貼圖已傳送

安其兒 星期一
❤️❤️❤️❤️

樂活 (21) 星期日

NTU CUBE EEW (8)

【三聯科技地震訊息服務】地震報告 CWB 2022-10-28_23:35:42 2022,10,28,23,30,43,緯度:24.62,經度:122.04,深度:63.9(km),規模:5.1,10/28-23:30臺灣東部海域發生規模5.1有感地震，最大震度宜蘭縣南澳、桃園市三光、花蓮縣西寶、桃園市3級。宜蘭縣政府東南東方 30.4 公里 (位於臺灣東部海域) 宜蘭縣地區:3級 桃園市地區:3級 花蓮縣地區:3級 新北市地區:2級 新竹縣地區:2級 臺中市地區:2級 南投縣地區:2級 彰化縣地區:2級 臺北市地區:1級 苗栗縣地區:1級 新竹市地區:1級 臺東縣地區:1級 嘉義縣地區:1級 雲林縣地區:1級 嘉義市地區:1級 基隆市地區:1級 。 下午 11:35

10月31日(一)

LINE Notify
【三聯科技地震訊息服務】2022-10-31_16:48:50 地震預警 CWB 地震震度:1級,倒數:45秒
【三聯科技地震訊息服務】2022-10-31_16:48:56 地震預警 CWB 地震震度:1級,倒數:40秒 下午 4:48

LINE Notify
【三聯科技地震訊息服務】2022-10-31_16:49:06 地震預警 CWB 地震震度:1級,倒數:30秒
【三聯科技地震訊息服務】2022-10-31_16:49:16 地震預警 CWB 地震震度:1級,倒數:20秒
【三聯科技地震訊息服務】2022-10-31_16:49:26 地震預警 CWB 地震震度:1級,倒數:10秒
【三聯科技地震訊息服務】2022-10-31_16:49:36 地震預警 CWB 地震震度:1級,倒數:0秒 下午 4:49

LINE Notify
【三聯科技地震訊息服務】地震報告 CWB 2022-10-31_16:53:53 2022,10,31,16,48,27,緯度:22.91,經度:121.21,深度:10.0(km),規模:5.0,10/31-16:48臺東縣東河鄉發生規模5.0有感地震，最大震度臺東縣鹿野、臺東縣臺東市4級。臺東縣政府北北東方 18.6 公里 (位於臺東縣東河鄉) 臺東縣地區:4級 花蓮縣地區:2級 高雄市地區:1級 屏東縣地區:1級 南投縣地區:1級 臺南市地區:1級 雲林縣地區:1級 嘉義縣地區:1級 嘉義市地區:1級 彰化縣地區:1級 。 下午 4:53

11月1日(二)

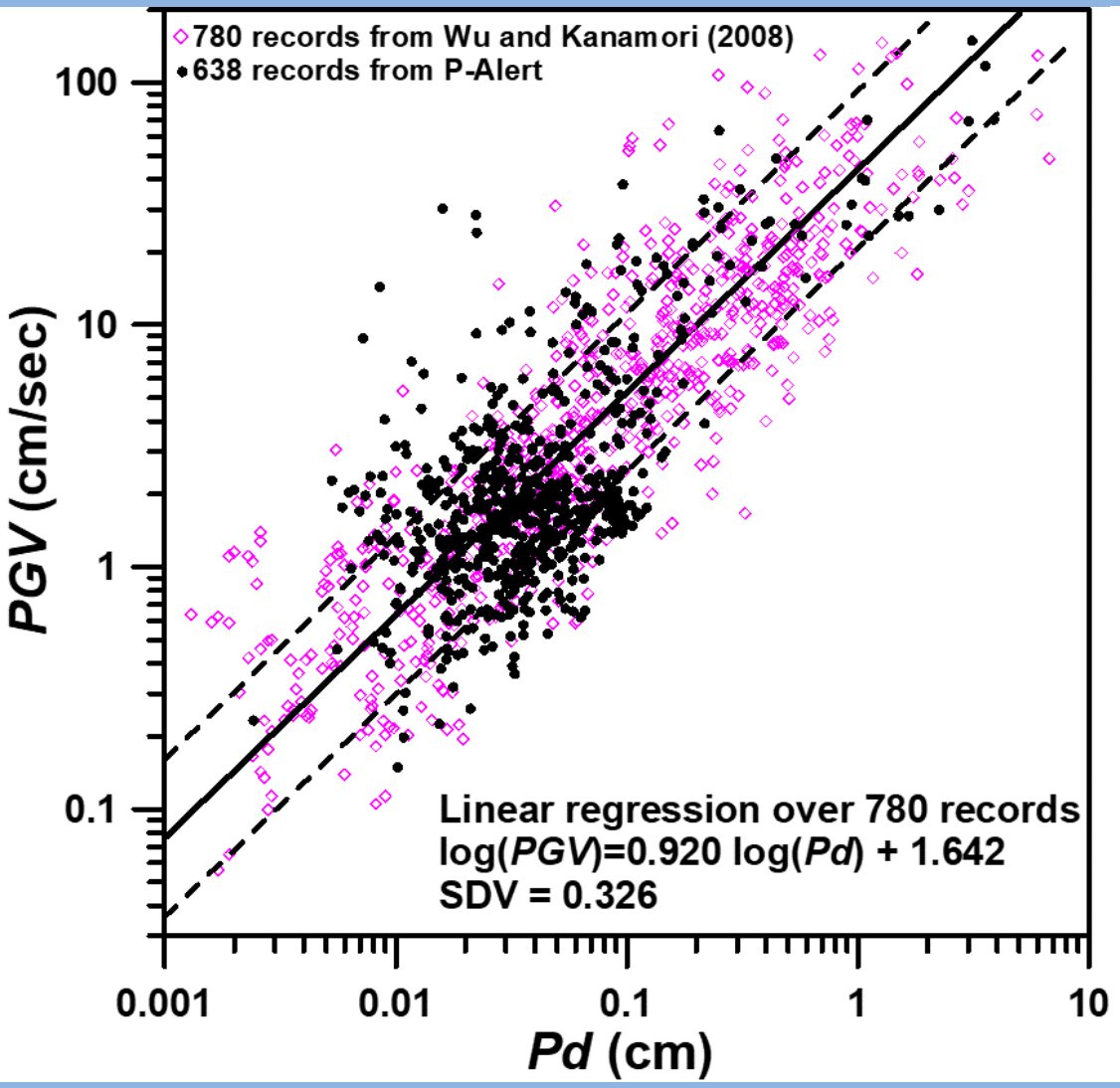
LINE Notify
【三聯科技地震訊息服務】地震報告 CWB 2022-11-01_13:47:21 2022,11,01,13,43,10,緯度:23.32,經度:121.48,深度:30.8(km),規模:4.4,11/01-13:43臺東縣近海發生規模4.4有感地震，最大震度臺東縣長濱3級。臺東縣政府北北東方 71.5 公里 (位於臺東縣近海) 臺東縣地區:3級 花蓮縣地區:2級 嘉義縣地區:1級 雲林縣地區:1級 南投縣地區:1級 彰化縣地區:1級 。 下午 1:47

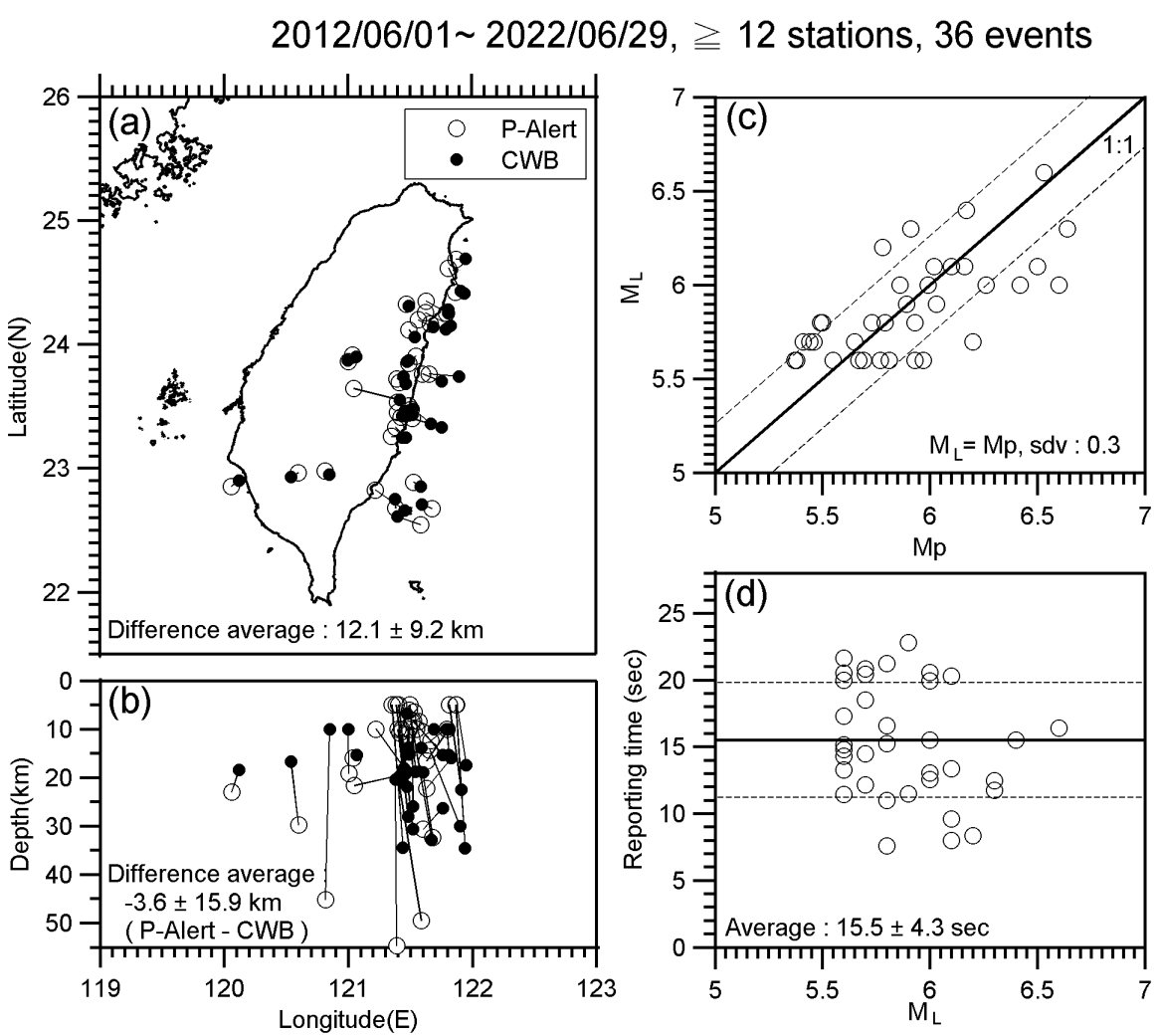
LINE Notify
【三聯科技地震訊息服務】2022-11-01_16:30:45 地震預警 CWB 地震震度:3級,倒數:-1秒
【三聯科技地震訊息服務】2022-11-01_16:30:46 地震預警 CWB 地震震度:3級,倒數:2秒

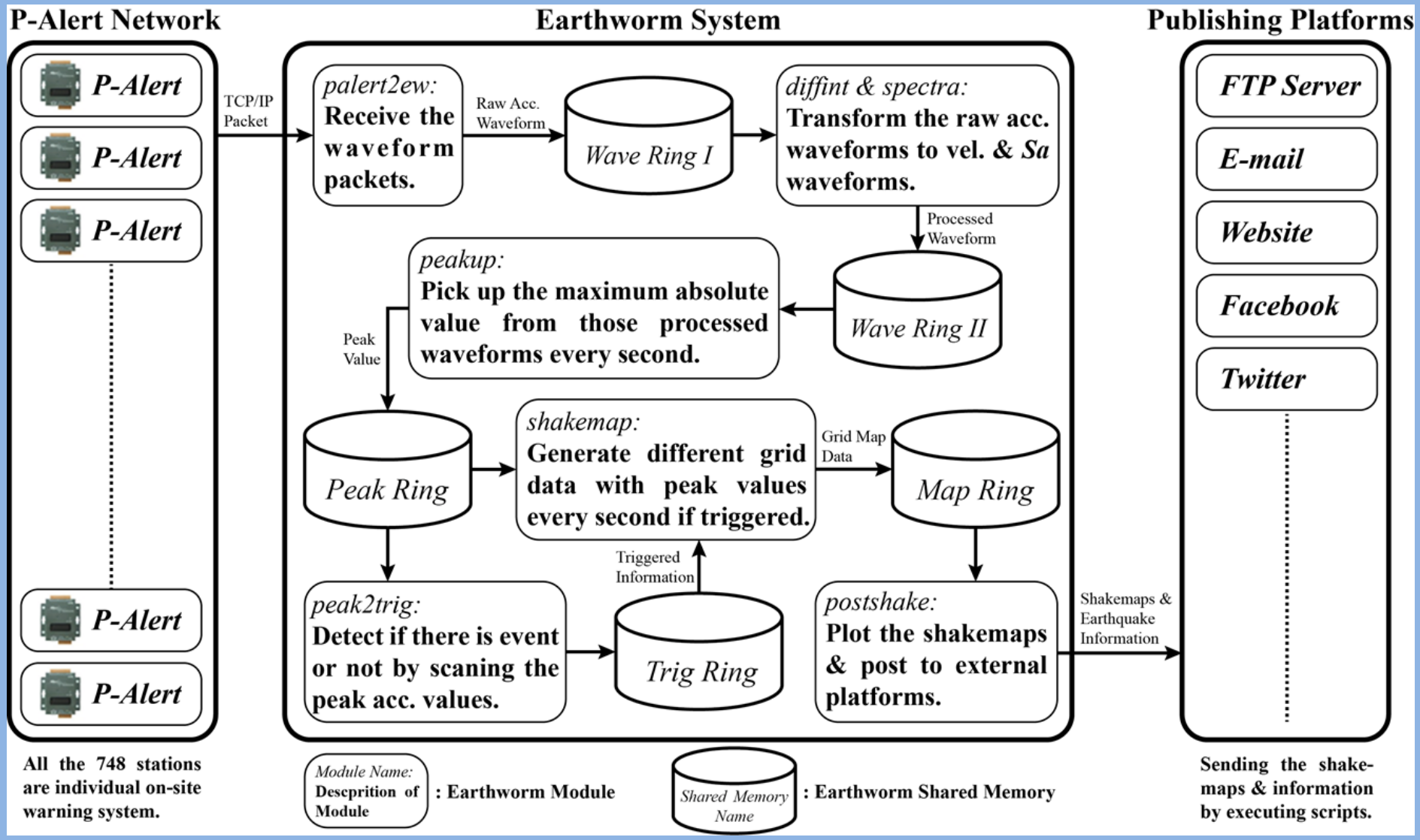
輸入訊息

在這裡輸入文字來搜尋

27°C 晴時多雲 英 下午 05:44 2022/11/11


780 records from Wu and Kanamori (2008)
638 records from P-Alert
Linear regression over 780 records
log(PGV)=0.920 log(Pd) + 1.642
SDV = 0.326
PGV (cm/sec)
Pd (cm)
100
10
1
0.1
0.001
0.01
0.1
1
10

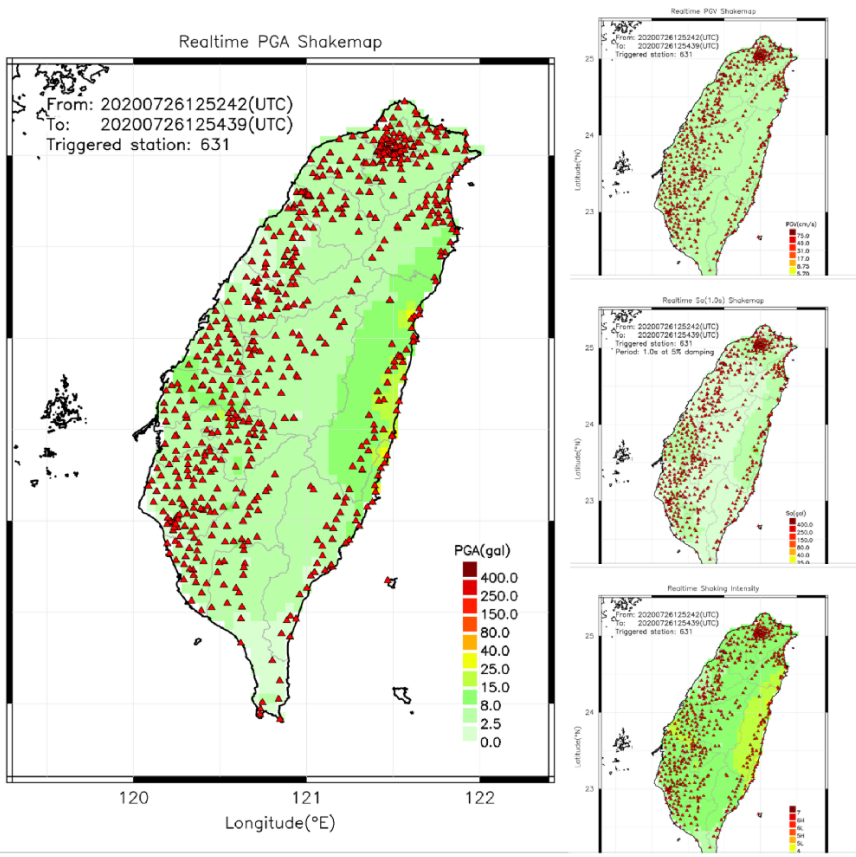

2012/06/01~ 2022/06/29, ≧ 12 stations, 36 events
(a)
P-Alert
CWB
Difference average : 12.1 ± 9.2 km
Latitude(N)
(b)
Depth(km)
Difference average
-3.6 ± 15.9 km
(P-Alert - CWB)
Longitude(E)
(c)
1:1
M_L= Mp, sdv : 0.3
M_L
Mp
(d)
Reporting time (sec)
Average : 15.5 ± 4.3 sec
M_L



Yang, B. M., H. Mittal, and Y. M. Wu (2021), Real-time producing PGA, PGV, Intensity, and Sa Shakemaps using Dense MEMS-Based Sensors in Taiwan, *Sensors*, **21**(3), 943, doi: 10.3390/s21030943.

NTU-Geo-EEW
Published by eew · July 26, 2020 ·

2020-07-26 20:54:39 自動繪製震度分佈圖
This shakemap is automatically generated by our EEW system.
It has not been confirmed yet. For reference only!



498
People Reached

47
Engagements

Boost Post

You and 3 others

1 Comment 1 Share

Like Comment Share

Most Relevant

Comment as NTU-Geo-EEW

Roy Chen
難怪剛剛想說怎麼震一下

Like · Reply · Message · 24w

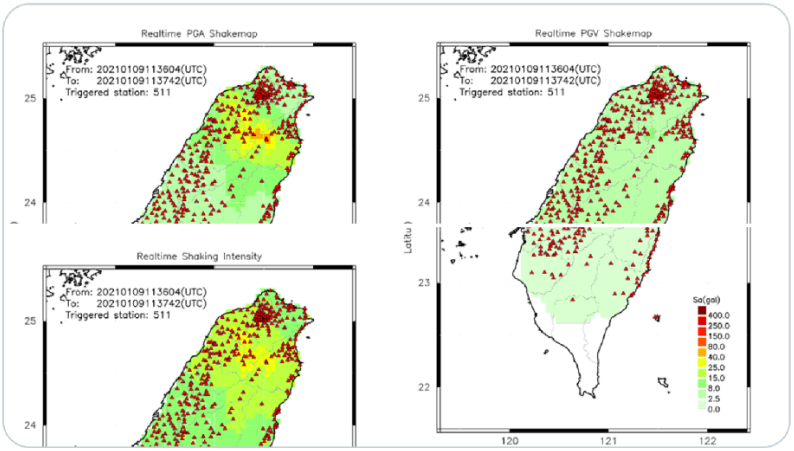
(a)

P-Alert EEW System
@eew_p

Replying to @eew_p

Automatically Plotted Shakemaps:
* 2021-01-09 19:37:42 (UTC+08:00, Taipei)
* Evt. 20210109193604, Final Report.
* Total 511 triggered stations

Note: These shakemaps are not yet confirmed, for reference only!
#地震 #台灣 #earthquake #Taiwan



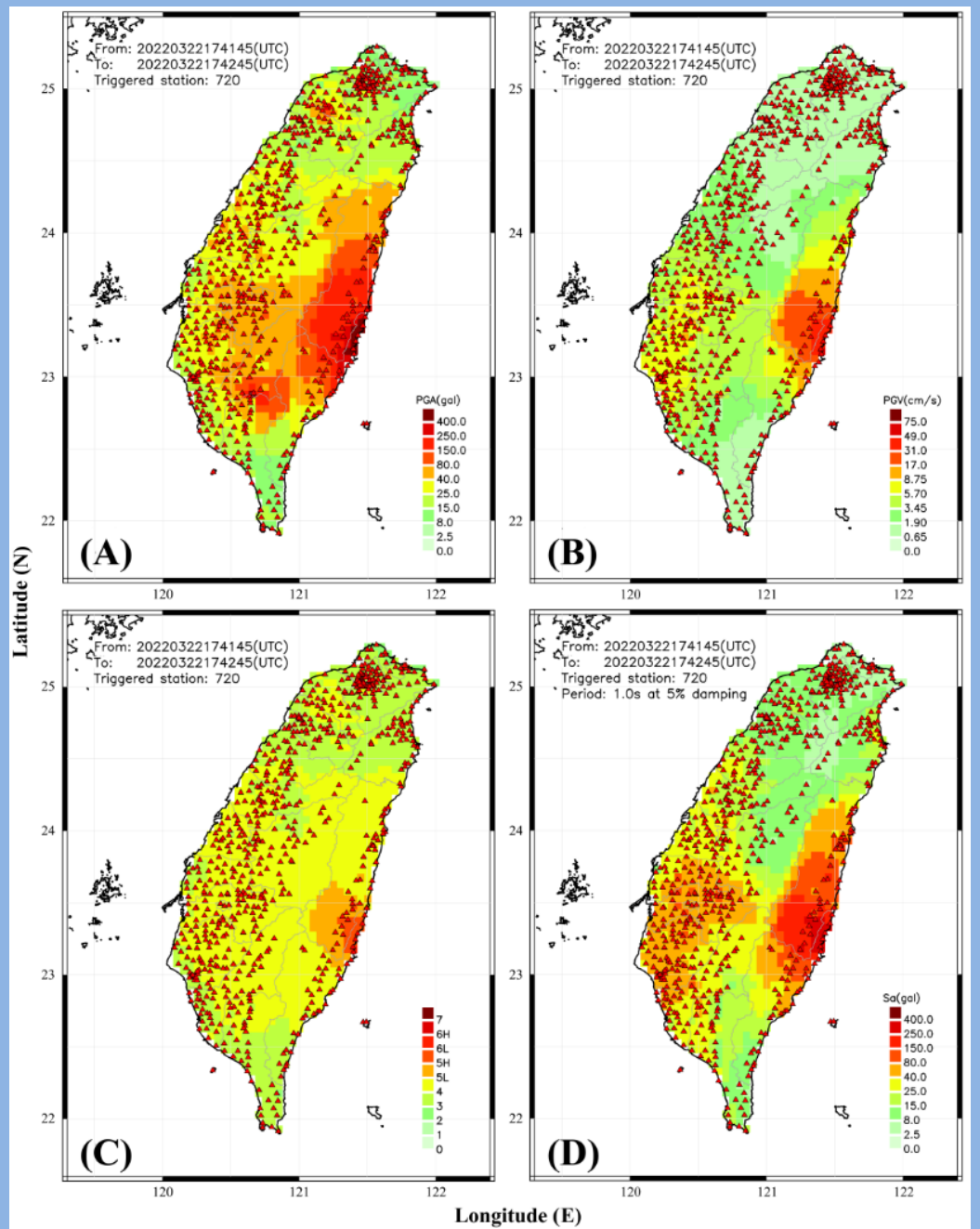
7:38 PM · Jan 9, 2021

View Tweet activity

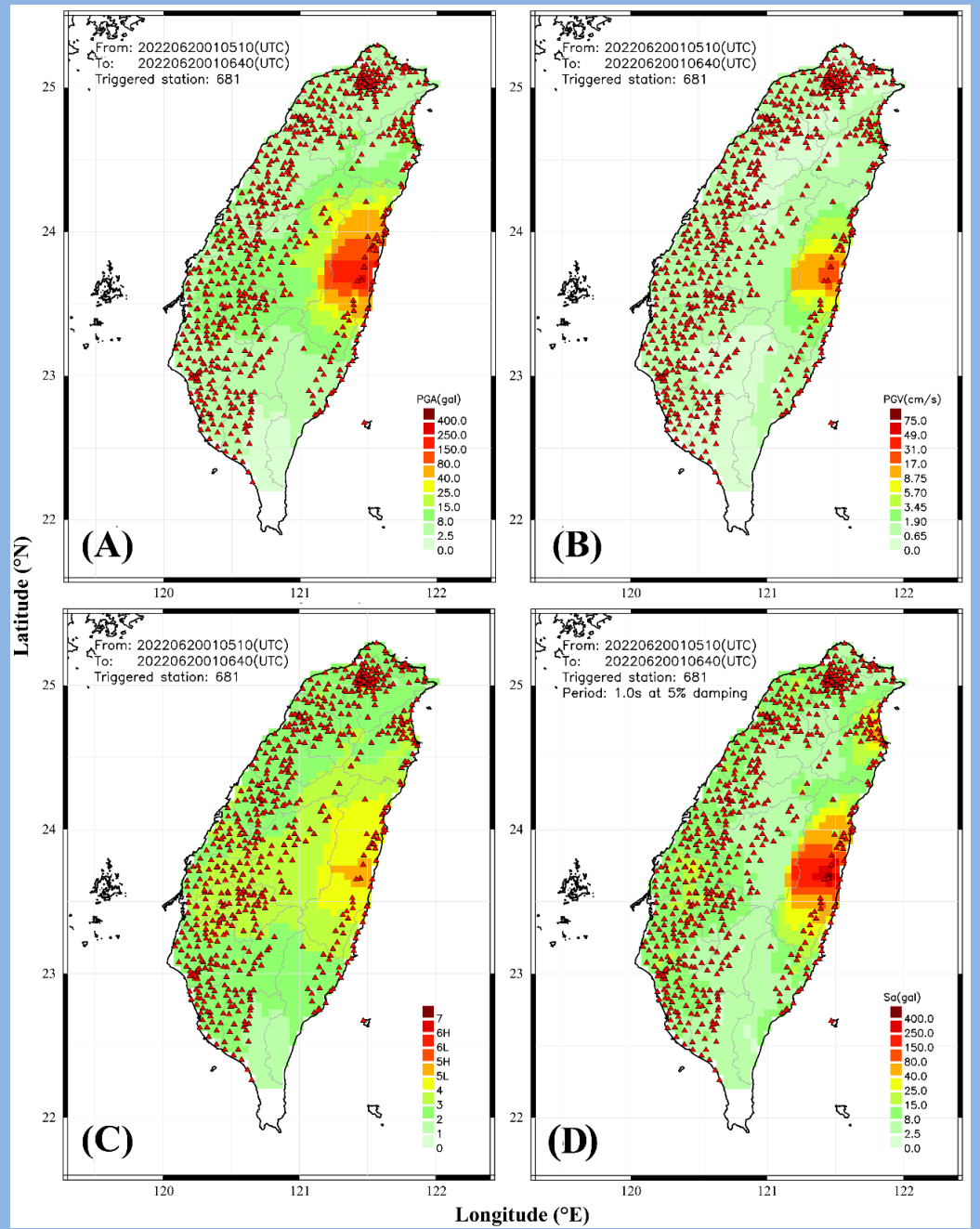
1 Retweet 1 Quote Tweet 5 Likes

(b)

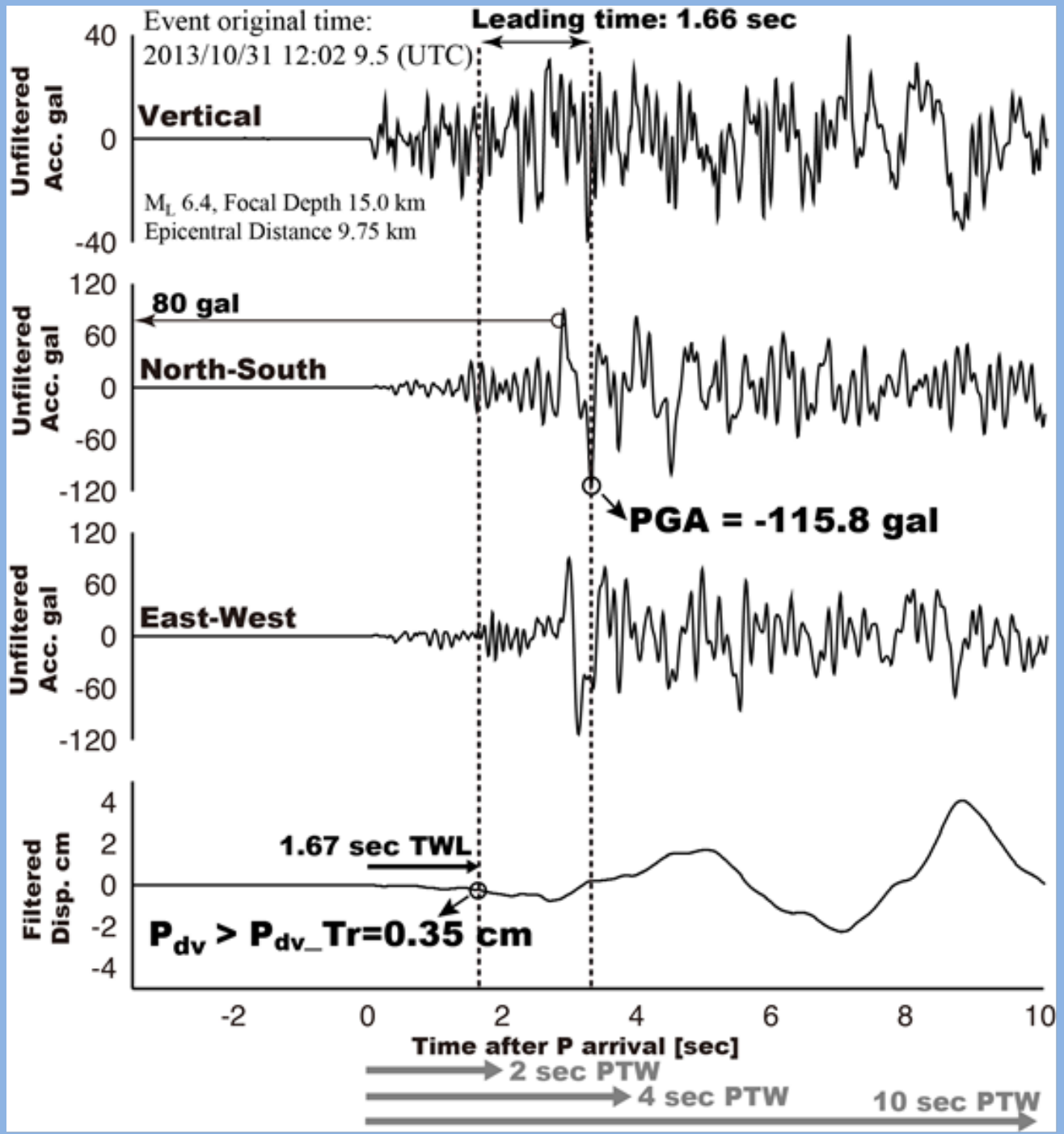
M_L 6.7 new intensity 6-

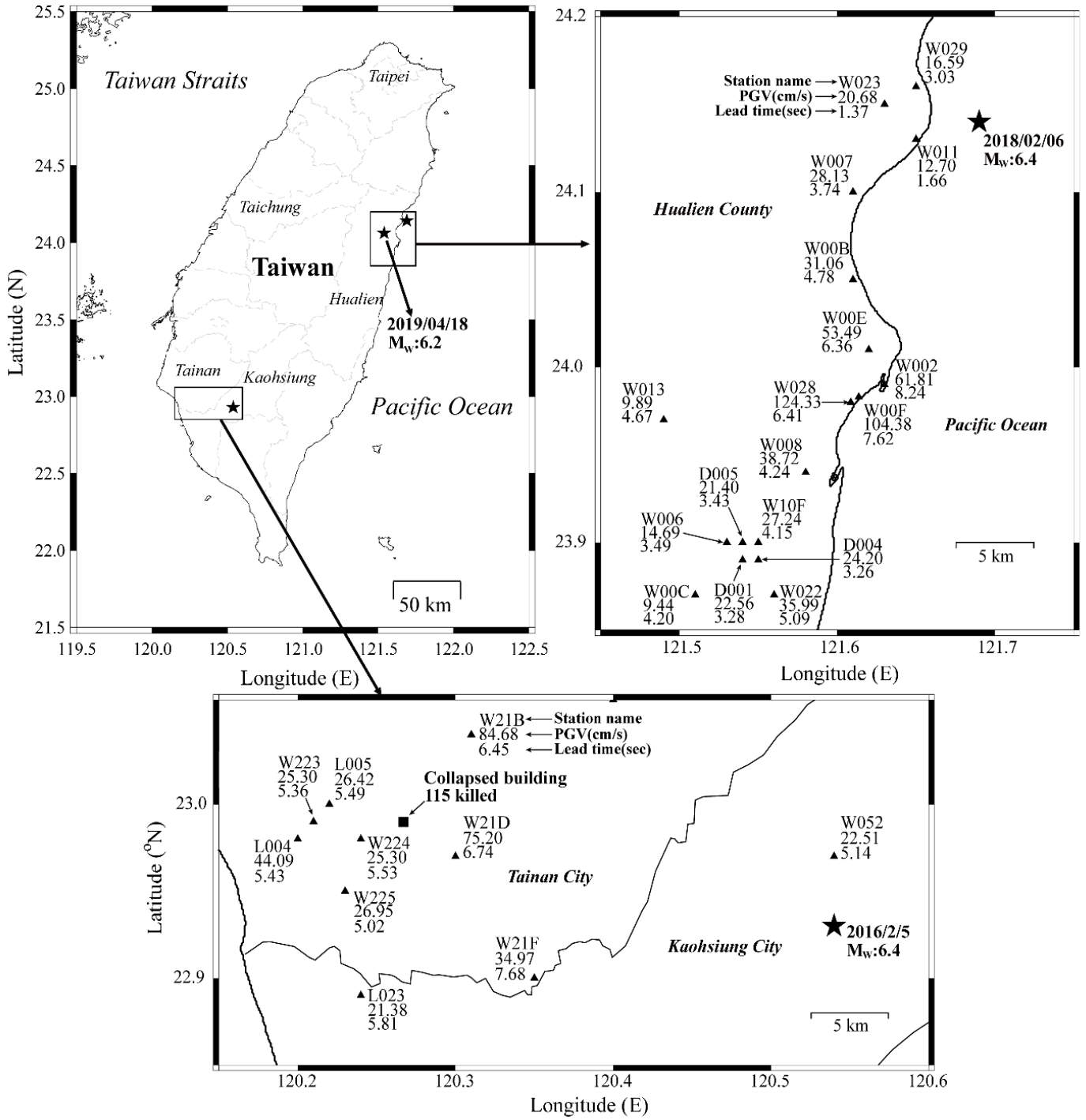


M_L 6.0 new intensity 5-

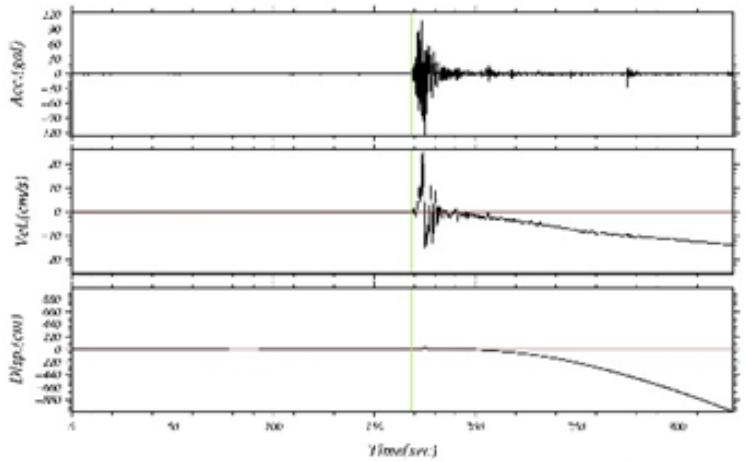


Pd Onsite Warning

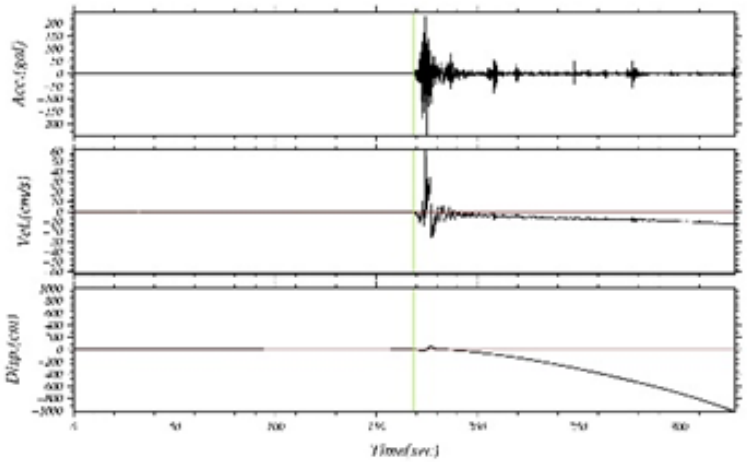



Taiwan Straits
Taipei
Taichung
Taiwan
Hualien
2019/04/18
Mw:6.2
Tainan
Kaohsiung
Pacific Ocean
50 km
Latitude (N)
Longitude (E)
Station name → W023
PGV(cm/s) → 20.68
Lead time(sec) → 1.37
W029 16.59 3.03
2018/02/06
Mw:6.4
W007 28.13 3.74
W011 12.70 1.66
Hualien County
W00B 31.06 4.78
W00E 53.49 6.36
W002 61.81 8.24
W013 9.89 4.67
W028 124.33 6.41
W00F 104.38 7.62
Pacific Ocean
W008 38.72 4.24
D005 21.40 3.43
W10F 27.24 4.15
W006 14.69 3.49
D004 24.20 3.26
5 km
W00C 9.44 4.20
D001 22.56 3.28
W022 35.99 5.09
W21B ← Station name
84.68 ← PGV(cm/s)
6.45 ← Lead time(sec)
W223 25.30 5.36
L005 26.42 5.49
Collapsed building
115 killed
W21D 75.20 6.74
L004 44.09 5.43
W224 25.30 5.53
W225 26.95 5.02
Tainan City
W052 22.51 5.14
2016/2/5
Mw:6.4
Kaohsiung City
W21F 34.97 7.68
L023 21.38 5.81
5 km
Latitude (°N)
Longitude (E)

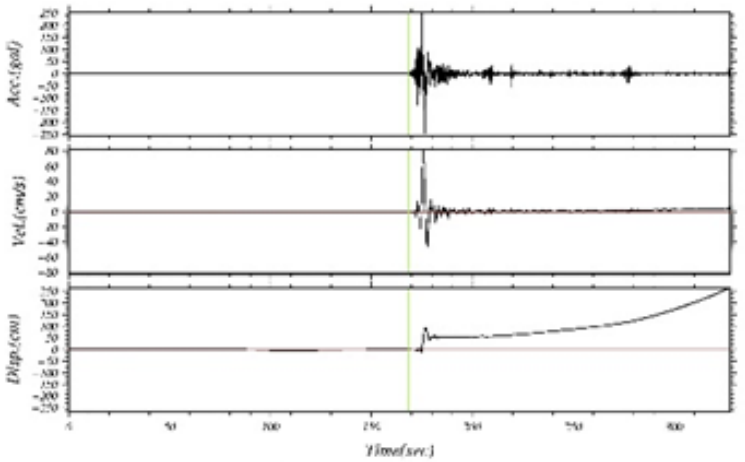
W002 Coseismic deformation



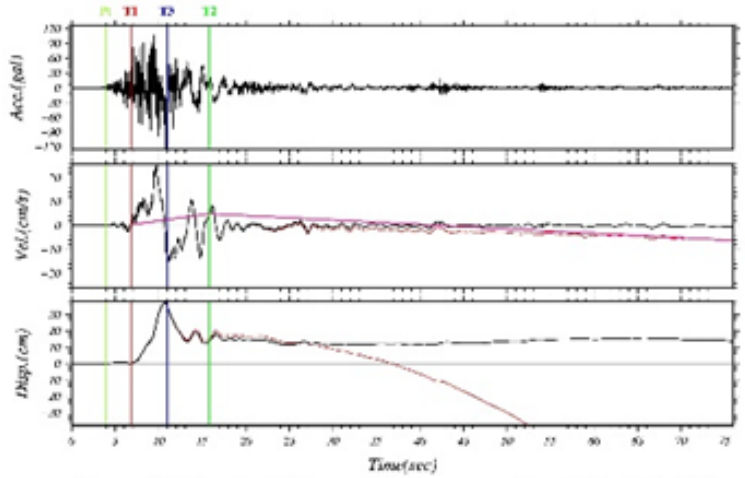
Filename=W002.inver2.dat, V Component W002



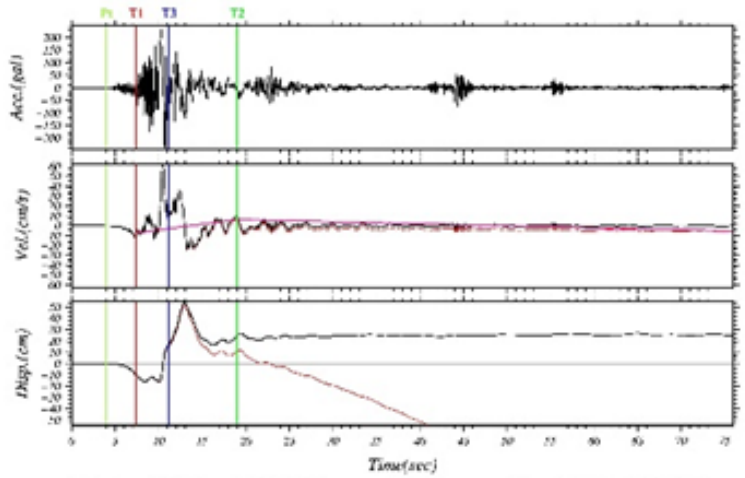
Filename=W002.inver2.dat, N−S Component W002



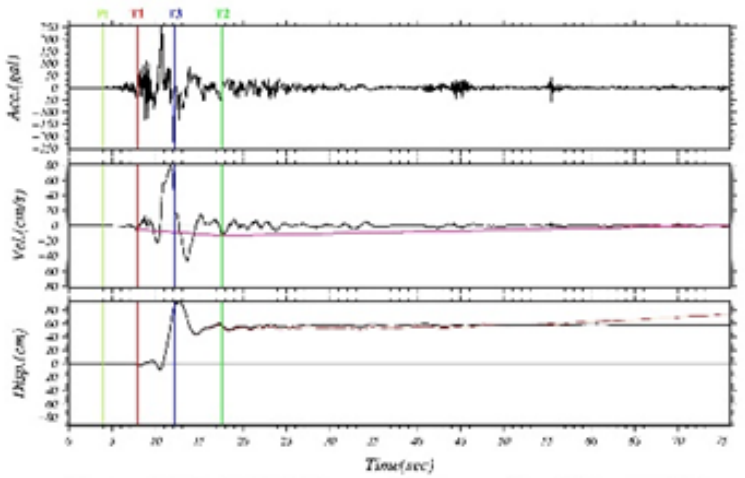
Filename=W002.inver2.dat, E−W Component W002



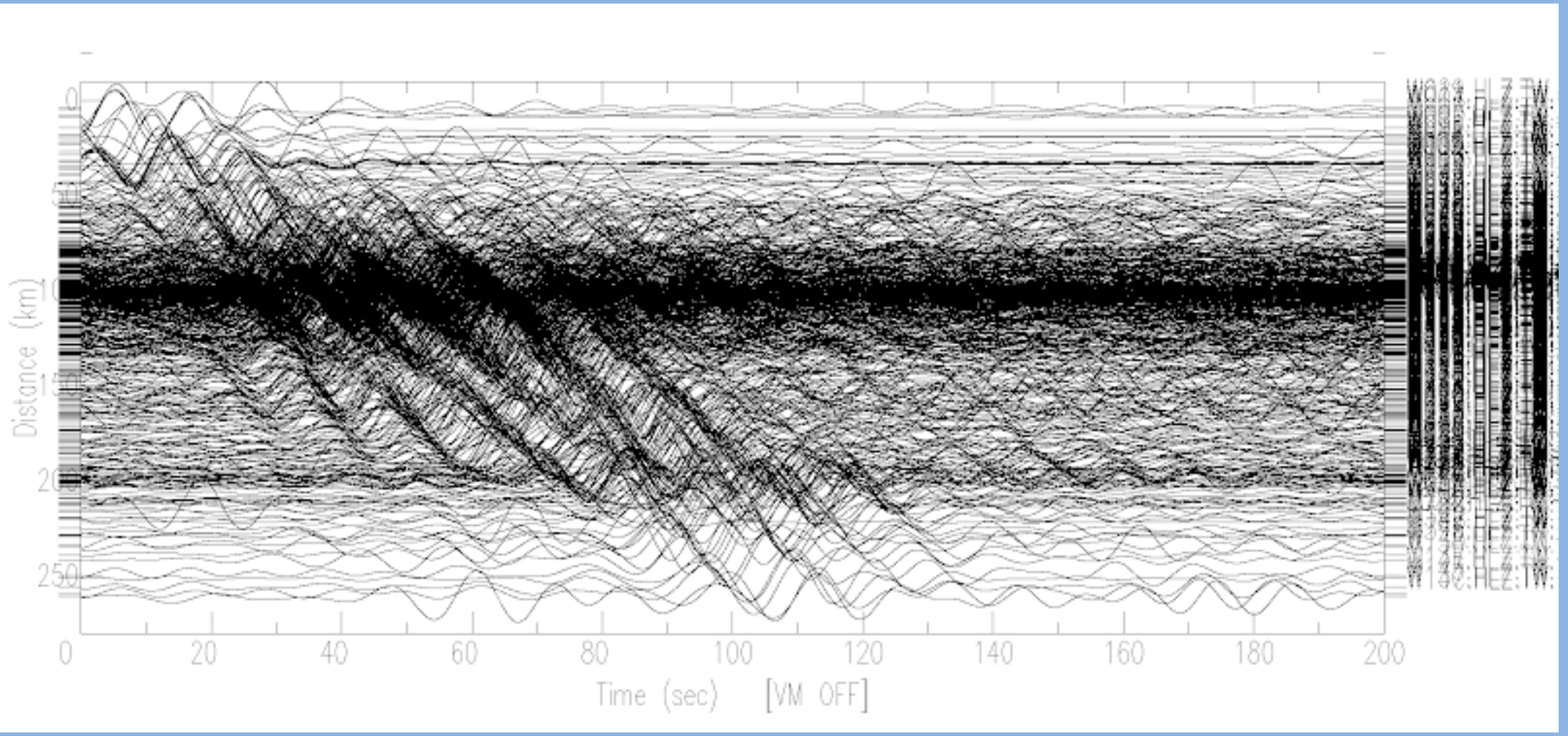
Filename=W002.inver2.dat, V Component W002 Disp.=14.05cm ISID=2.53cm



Filename=W002.inver2.dat, N−S Component W002 Disp.=25.25cm ISID=4.22cm



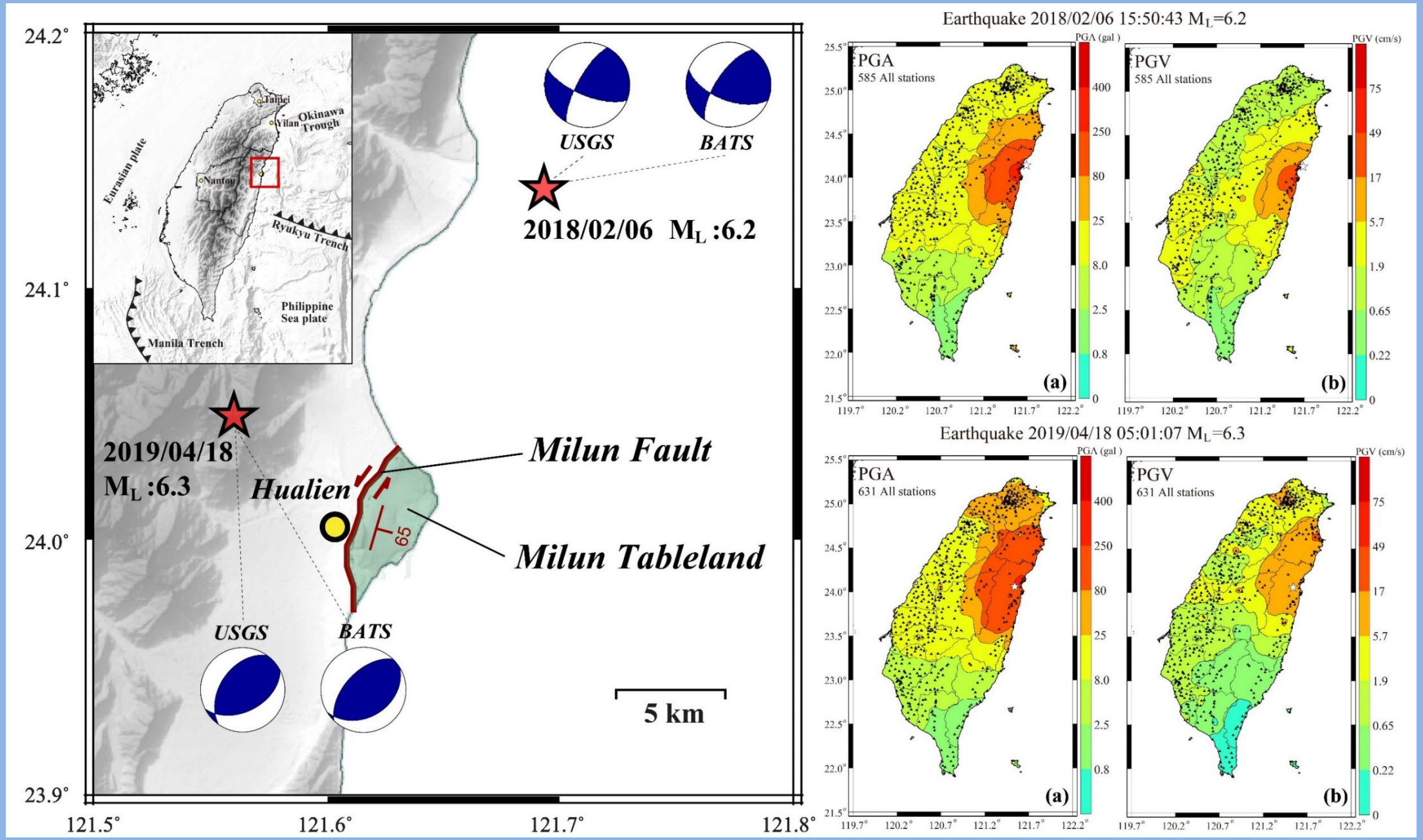
Filename=W002.inver2.dat, E−W Component W002 Disp.=57.80cm ISID=4.98cm

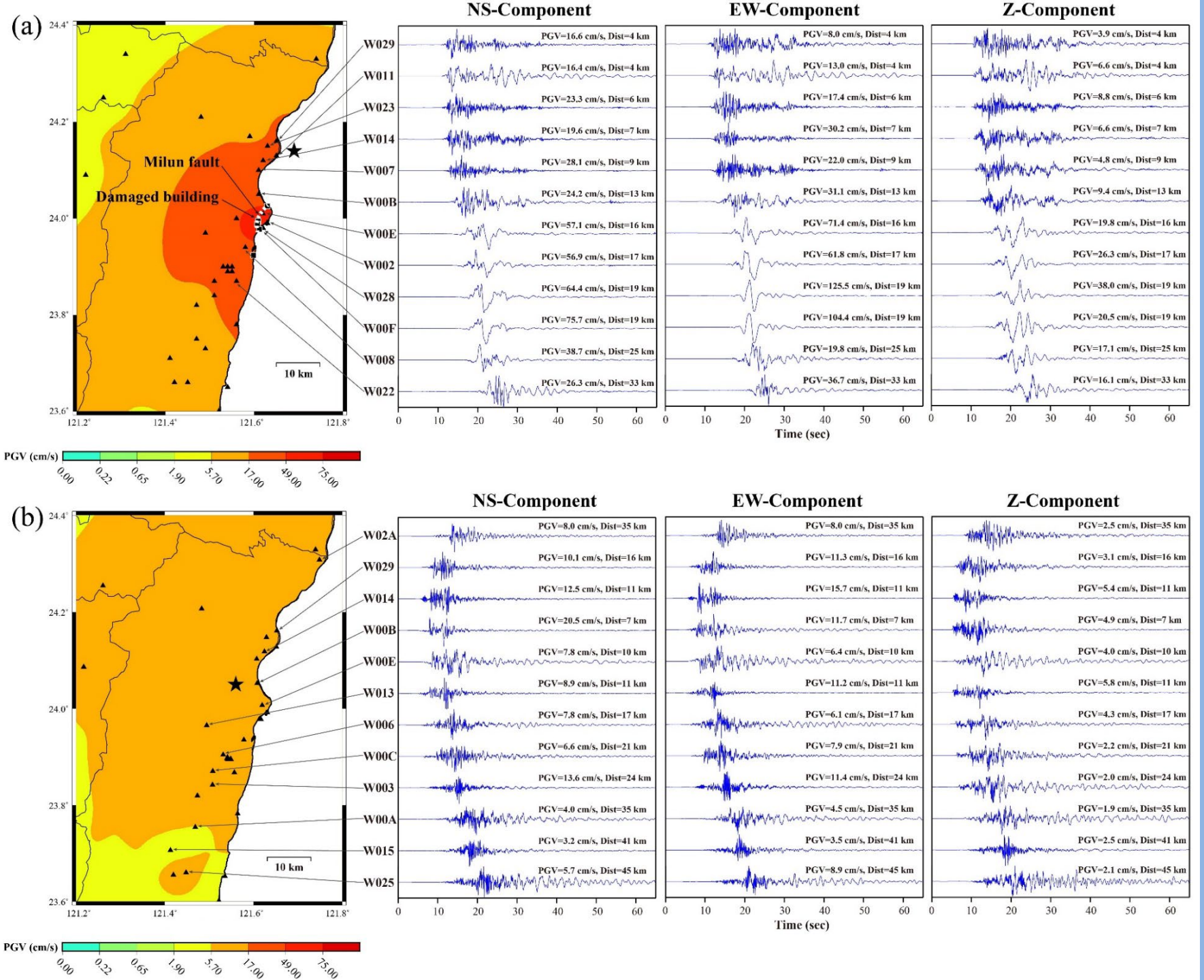


P-Alert waveform can be downloaded in near real-time @ http://palert.earth.sinica.edu.tw/db/

Importance of real-time PGV Shakemap

Mittal, H., B. M. Yang, T. L. Tseng, and Y. M. Wu (2021), Importance of real-time PGV in terms of lead-time and shakemaps: Results using 2018 M_L 6.2 & 2019 M_L 6.3 Hualien, Taiwan Earthquakes, accepted by *Journal of Asian Earth Sciences*.

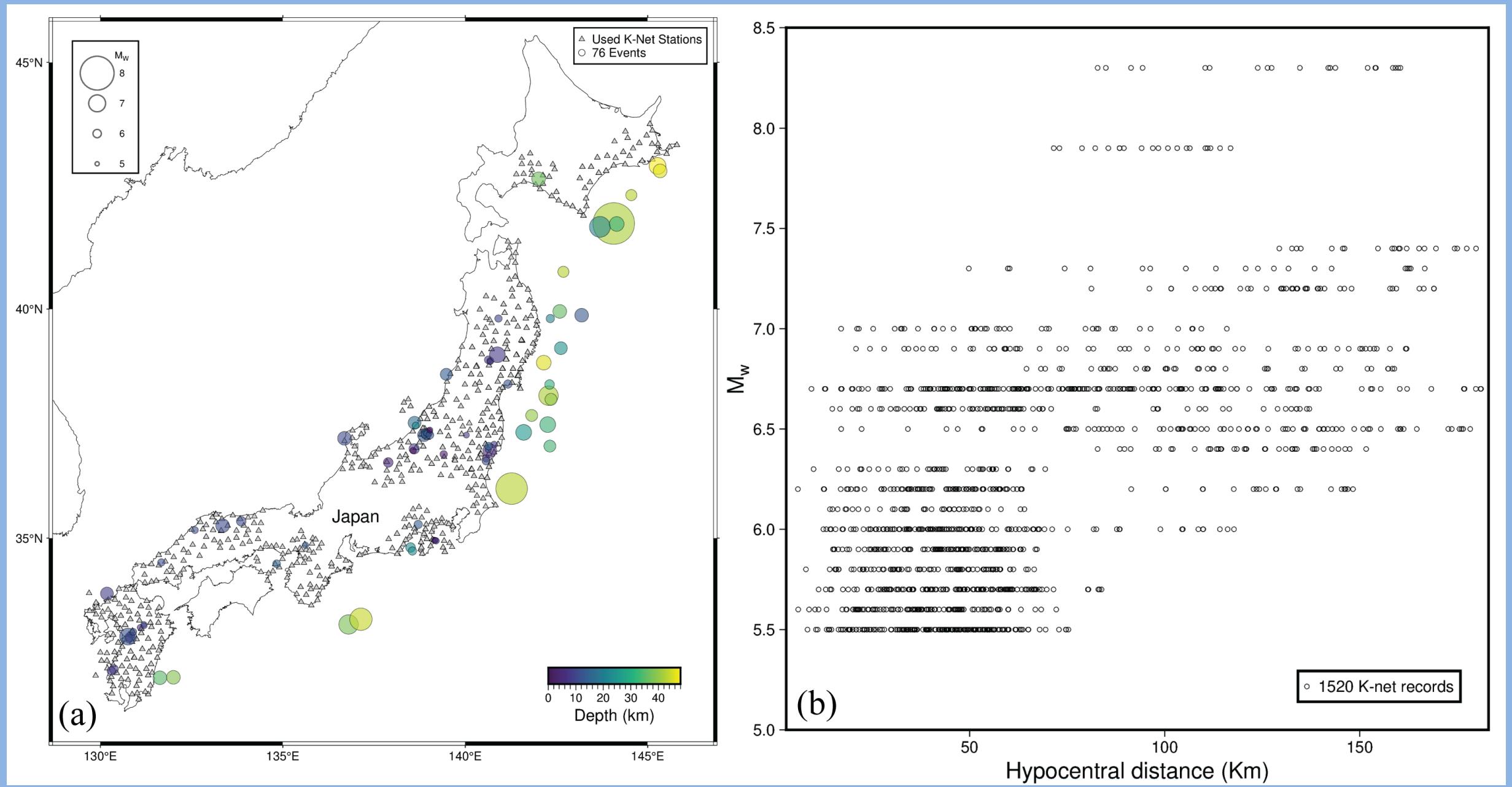

24.2°
24.1°
24.0°
23.9°
121.5°
121.6°
121.7°
121.8°
Taipei
Yilan
Okinawa Trough
Eurasian plate
Nantou
Ryukyu Trench
Philippine Sea plate
Manila Trench
USGS
BATS
2018/02/06 M_L :6.2
2019/04/18
M_L :6.3
Hualien
Milun Fault
Milun Tableland
65
USGS
BATS
5 km
Earthquake 2018/02/06 15:50:43 M_L=6.2
PGA
585 All stations
PGA (gal)
400
250
80
25
8.0
2.5
0.8
0
(a)
PGV
585 All stations
PGV (cm/s)
75
49
17
5.7
1.9
0.65
0.22
0
(b)
Earthquake 2019/04/18 05:01:07 M_L=6.3
PGA
631 All stations
PGA (gal)
(a)
PGV
631 All stations
PGV (cm/s)
(b)

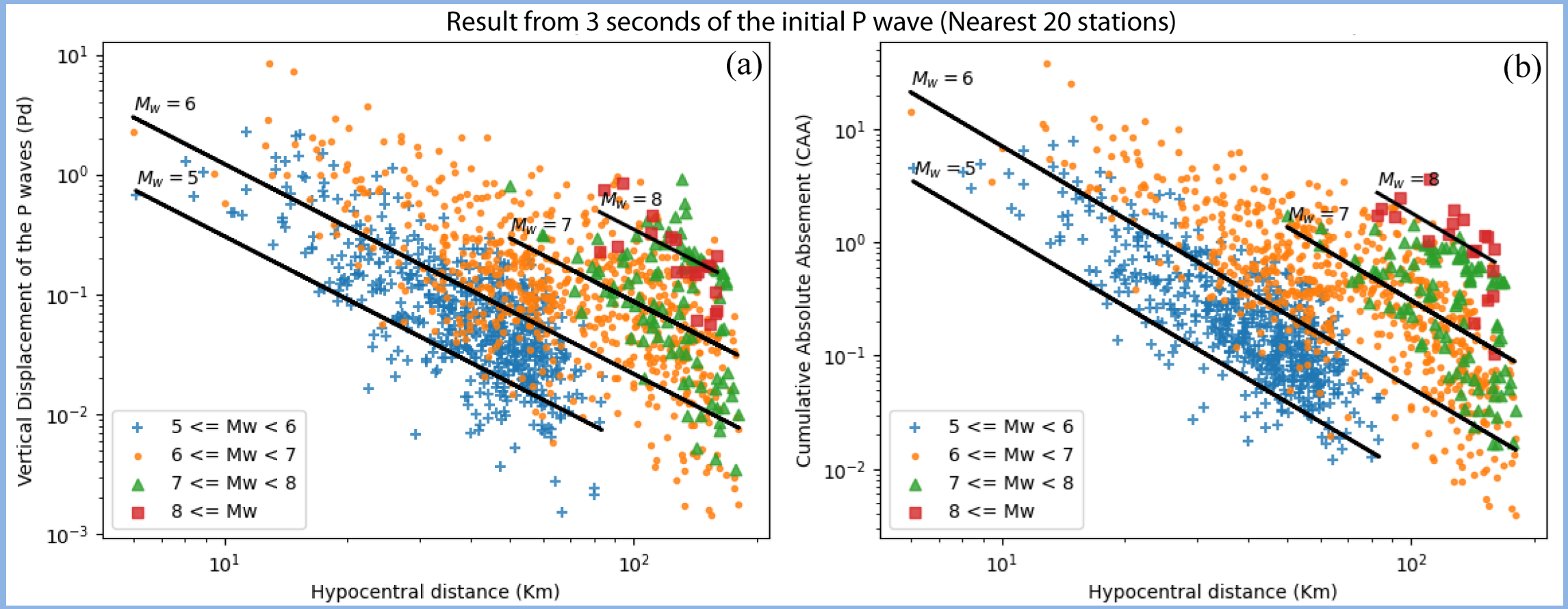

(a)
NS-Component
EW-Component
Z-Component
Milun fault
Damaged building
10 km
W029
W011
W023
W014
W007
W00B
W00E
W002
W028
W00F
W008
W022
PGV=16.6 cm/s, Dist=4 km
PGV=16.4 cm/s, Dist=4 km
PGV=23.3 cm/s, Dist=6 km
PGV=19.6 cm/s, Dist=7 km
PGV=28.1 cm/s, Dist=9 km
PGV=24.2 cm/s, Dist=13 km
PGV=57.1 cm/s, Dist=16 km
PGV=56.9 cm/s, Dist=17 km
PGV=64.4 cm/s, Dist=19 km
PGV=75.7 cm/s, Dist=19 km
PGV=38.7 cm/s, Dist=25 km
PGV=26.3 cm/s, Dist=33 km
PGV=8.0 cm/s, Dist=4 km
PGV=13.0 cm/s, Dist=4 km
PGV=17.4 cm/s, Dist=6 km
PGV=30.2 cm/s, Dist=7 km
PGV=22.0 cm/s, Dist=9 km
PGV=31.1 cm/s, Dist=13 km
PGV=71.4 cm/s, Dist=16 km
PGV=61.8 cm/s, Dist=17 km
PGV=125.5 cm/s, Dist=19 km
PGV=104.4 cm/s, Dist=19 km
PGV=19.8 cm/s, Dist=25 km
PGV=36.7 cm/s, Dist=33 km
PGV=3.9 cm/s, Dist=4 km
PGV=6.6 cm/s, Dist=4 km
PGV=8.8 cm/s, Dist=6 km
PGV=6.6 cm/s, Dist=7 km
PGV=4.8 cm/s, Dist=9 km
PGV=9.4 cm/s, Dist=13 km
PGV=19.8 cm/s, Dist=16 km
PGV=26.3 cm/s, Dist=17 km
PGV=38.0 cm/s, Dist=19 km
PGV=20.5 cm/s, Dist=19 km
PGV=17.1 cm/s, Dist=25 km
PGV=16.1 cm/s, Dist=33 km
24.4°
24.2°
24.0°
23.8°
23.6°
121.2°
121.4°
121.6°
121.8°
0
10
20
30
40
50
60
Time (sec)
PGV (cm/s)
0.00
0.22
0.65
1.90
5.70
17.00
49.00
75.00
(b)
NS-Component
EW-Component
Z-Component
10 km
W02A
W029
W014
W00B
W00E
W013
W006
W00C
W003
W00A
W015
W025
PGV=8.0 cm/s, Dist=35 km
PGV=10.1 cm/s, Dist=16 km
PGV=12.5 cm/s, Dist=11 km
PGV=20.5 cm/s, Dist=7 km
PGV=7.8 cm/s, Dist=10 km
PGV=8.9 cm/s, Dist=11 km
PGV=7.8 cm/s, Dist=17 km
PGV=6.6 cm/s, Dist=21 km
PGV=13.6 cm/s, Dist=24 km
PGV=4.0 cm/s, Dist=35 km
PGV=3.2 cm/s, Dist=41 km
PGV=5.7 cm/s, Dist=45 km
PGV=8.0 cm/s, Dist=35 km
PGV=11.3 cm/s, Dist=16 km
PGV=15.7 cm/s, Dist=11 km
PGV=11.7 cm/s, Dist=7 km
PGV=6.4 cm/s, Dist=10 km
PGV=11.2 cm/s, Dist=11 km
PGV=6.1 cm/s, Dist=17 km
PGV=7.9 cm/s, Dist=21 km
PGV=11.4 cm/s, Dist=24 km
PGV=4.5 cm/s, Dist=35 km
PGV=3.5 cm/s, Dist=41 km
PGV=8.9 cm/s, Dist=45 km
PGV=2.5 cm/s, Dist=35 km
PGV=3.1 cm/s, Dist=16 km
PGV=5.4 cm/s, Dist=11 km
PGV=4.9 cm/s, Dist=7 km
PGV=4.0 cm/s, Dist=10 km
PGV=5.8 cm/s, Dist=11 km
PGV=4.3 cm/s, Dist=17 km
PGV=2.2 cm/s, Dist=21 km
PGV=2.0 cm/s, Dist=24 km
PGV=1.9 cm/s, Dist=35 km
PGV=2.5 cm/s, Dist=41 km
PGV=2.1 cm/s, Dist=45 km
24.4°
24.2°
24.0°
23.8°
23.6°
121.2°
121.4°
121.6°
121.8°
0
10
20
30
40
50
60
Time (sec)
PGV (cm/s)
0.00
0.22
0.65
1.90
5.70
17.00
49.00
75.00

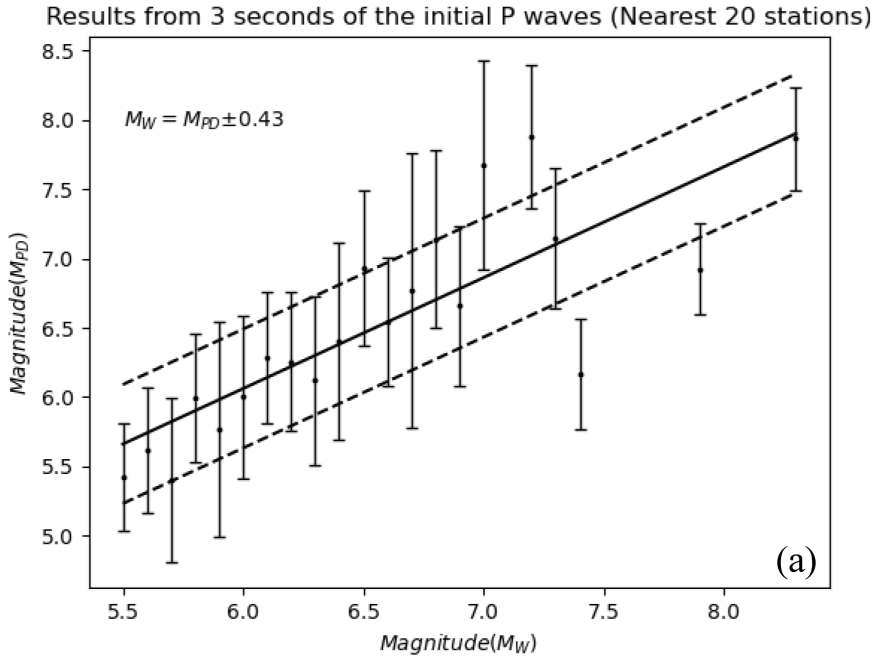
Magnitude determination using cumulative absolute absement (CAA) for earthquake early warning

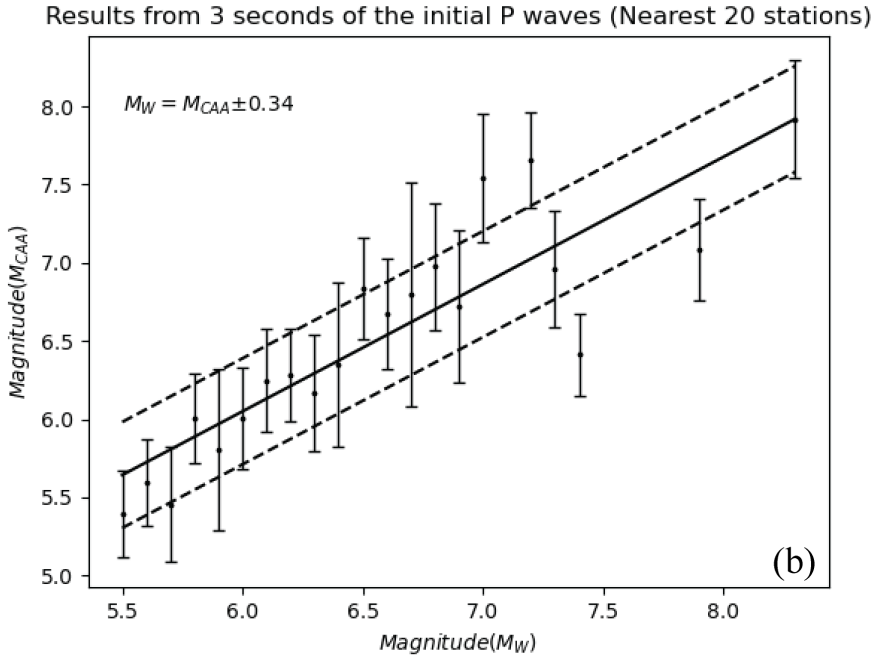
$$CAV = \int_{T_p}^{T_{p+i}} \sqrt{Av^2 + An^2 + Ae^2}\, dt$$

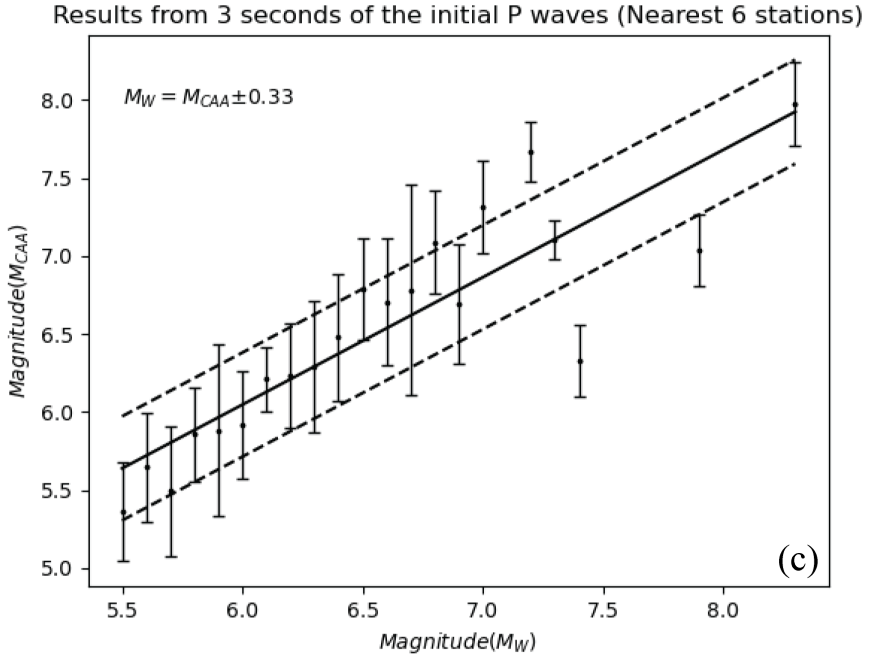
$$CAA = \int_{T_p}^{T_{p+i}} \sqrt{Dv^2 + Dn^2 + De^2}\, dt$$

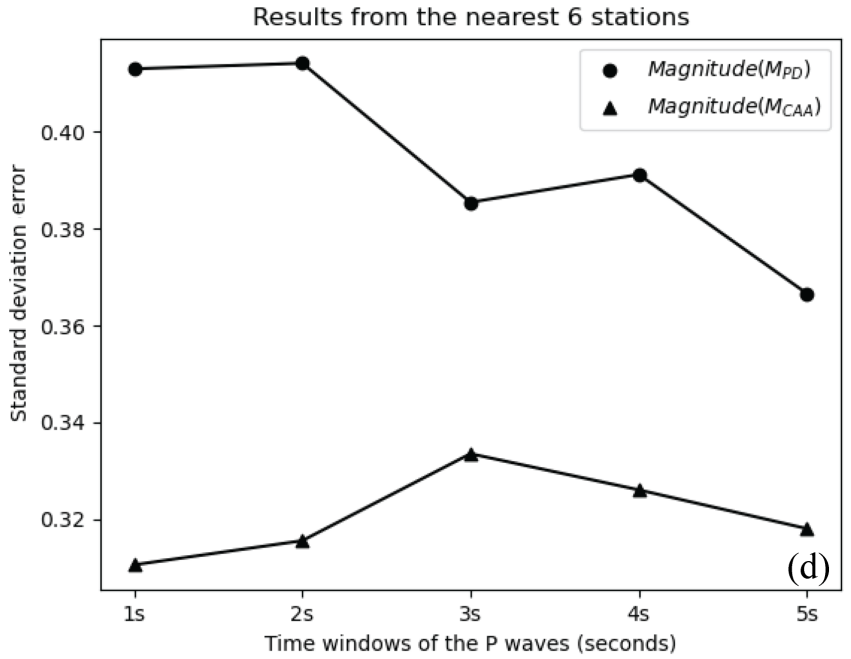

Used K-Net Stations
76 Events
Mw
8
7
6
5
45°N
40°N
35°N
130°E
135°E
140°E
145°E
Japan
0 10 20 30 40
Depth (km)
(a)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
Mw
50
100
150
Hypocentral distance (Km)
1520 K-net records
(b)


Result from 3 seconds of the initial P wave (Nearest 20 stations)
(a)
Vertical Displacement of the P waves (Pd)
$M_w = 6$
$M_w = 5$
$M_w = 7$
$M_w = 8$
5 <= Mw < 6
6 <= Mw < 7
7 <= Mw < 8
8 <= Mw
Hypocentral distance (Km)
(b)
Cumulative Absolute Absement (CAA)
$M_w = 6$
$M_w = 5$
$M_w = 7$
$M_w = 8$
5 <= Mw < 6
6 <= Mw < 7
7 <= Mw < 8
8 <= Mw
Hypocentral distance (Km)


Results from 3 seconds of the initial P waves (Nearest 20 stations)
$M_W = M_{PD} \pm 0.43$
Magnitude(M_{PD})
Magnitude(M_W)
(a)

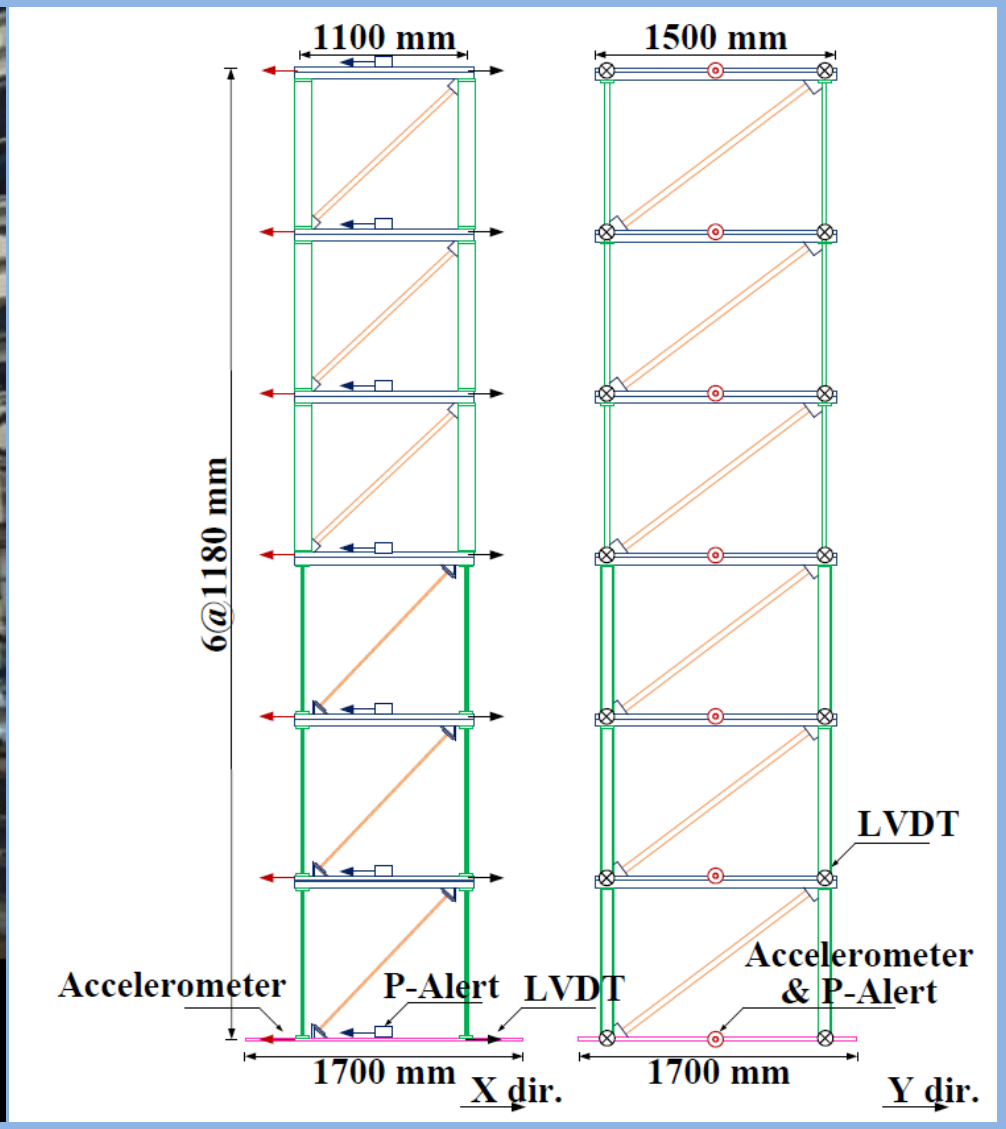

Results from 3 seconds of the initial P waves (Nearest 20 stations)
$M_W = M_{CAA} \pm 0.34$
Magnitude(M_{CAA})
Magnitude(M_W)
(b)


Results from 3 seconds of the initial P waves (Nearest 6 stations)
$M_W = M_{CAA} \pm 0.33$
Magnitude(M_{CAA})
Magnitude(M_W)
(c)


Results from the nearest 6 stations
Magnitude(M_{PD})
Magnitude(M_{CAA})
Standard deviation error
Time windows of the P waves (seconds)
(d)

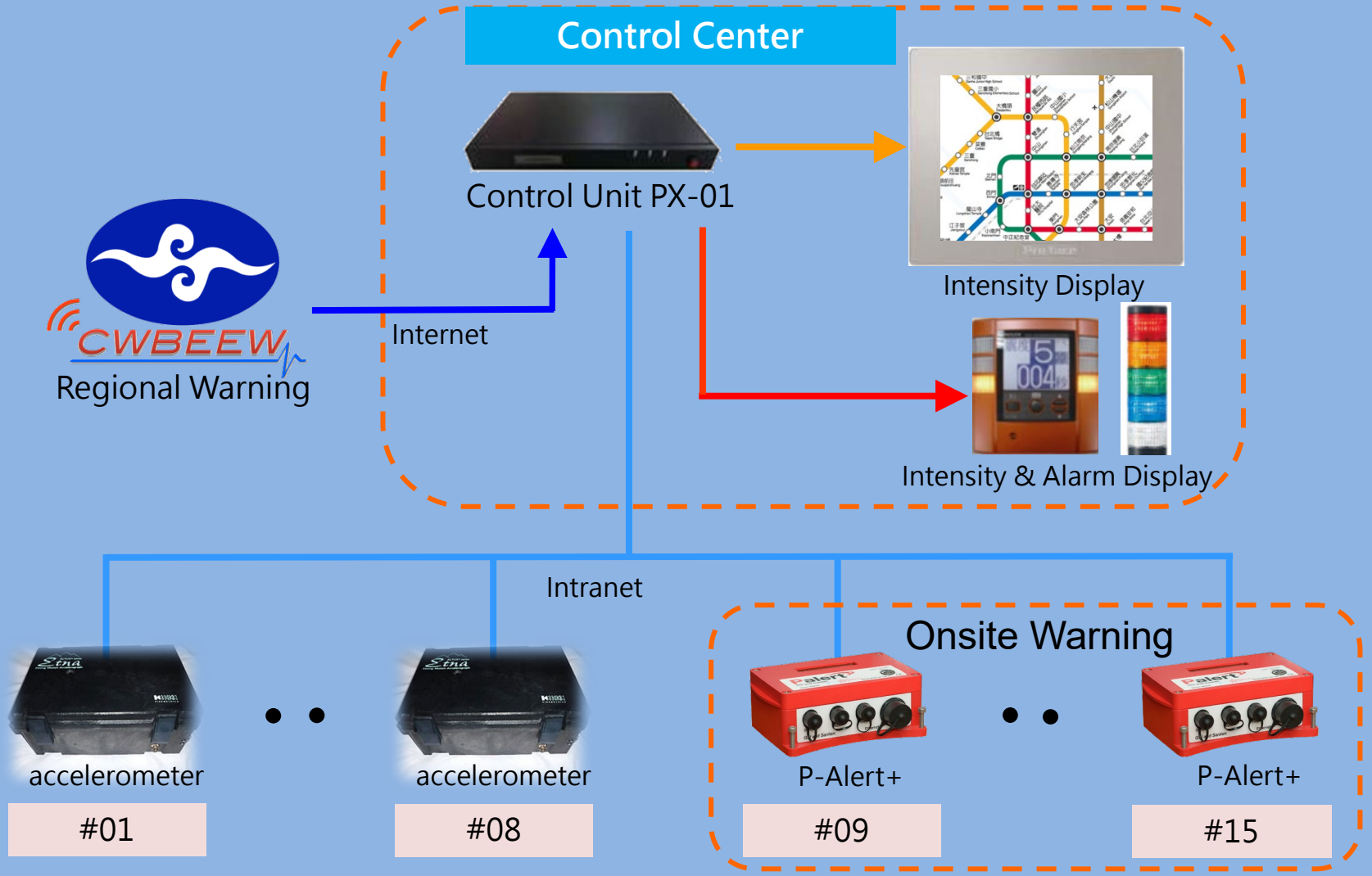
Some applications

From early warning to structural health monitoring

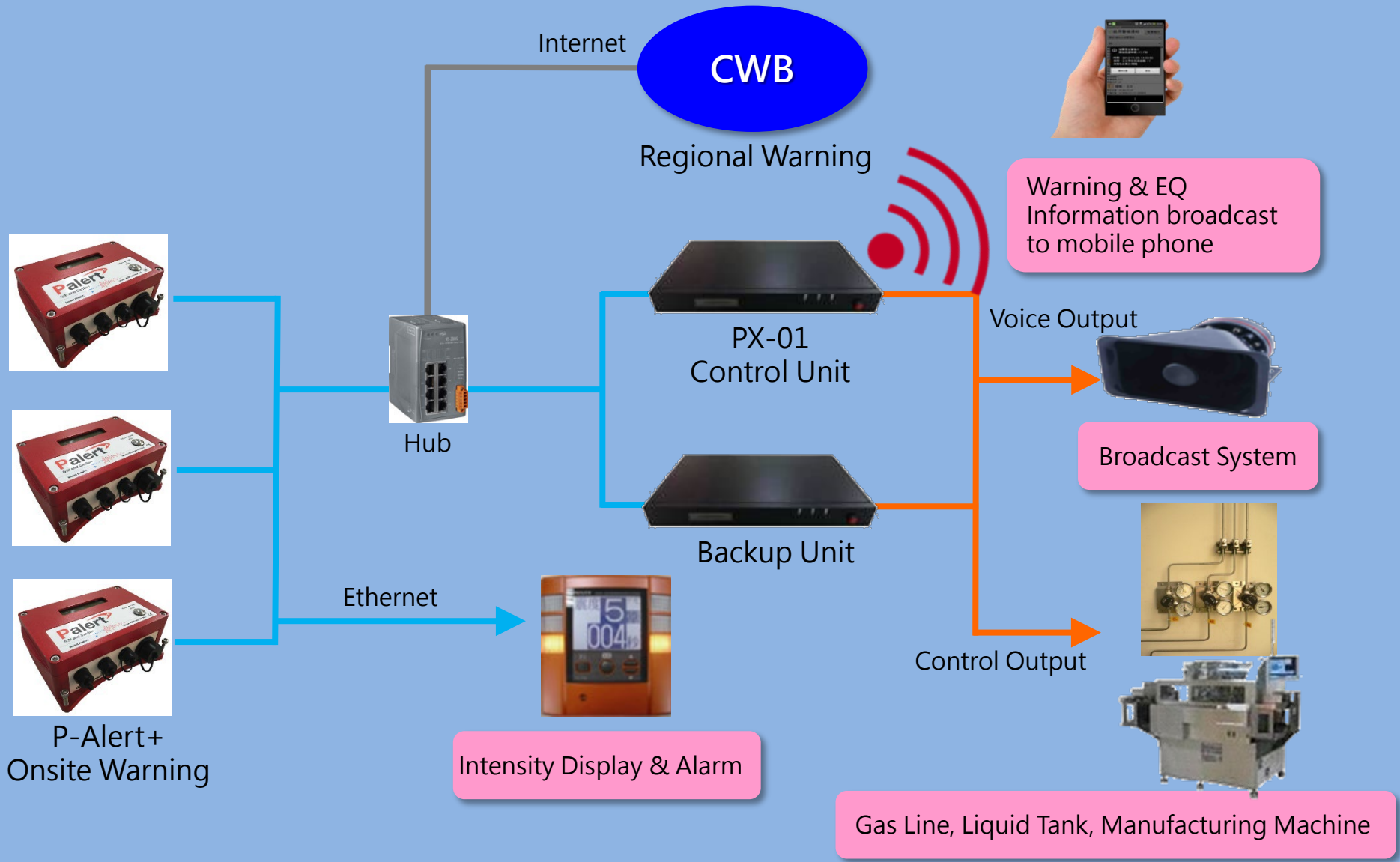


Hsu, T. Y., R. C. Yin, and Y. M. Wu (2018), Evaluating Post-Earthquake Building Safety Using Economical MEMS Seismometers, *Sensors* **18**, 1437, doi: 10.3390/s18051437.

Taipei MRT EEW system



Tainan Science Park EEW system




Korea
Greece
China
Taiwan
Nepal
Buhtan
Philippines
Vietnam
India
Solomon
Islands
Indonesia
New Zealand
US Dept of State Geographer
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Summary of Low Cost System

- Both Onsite and regional EEW
- Rapid reporting with real-time shaking map
- Low cost and easy maintaining
- Low cost and dense array in operation

Thanks for your attention!