Surface Deformation and Seismic Rebound: Implications and Applications

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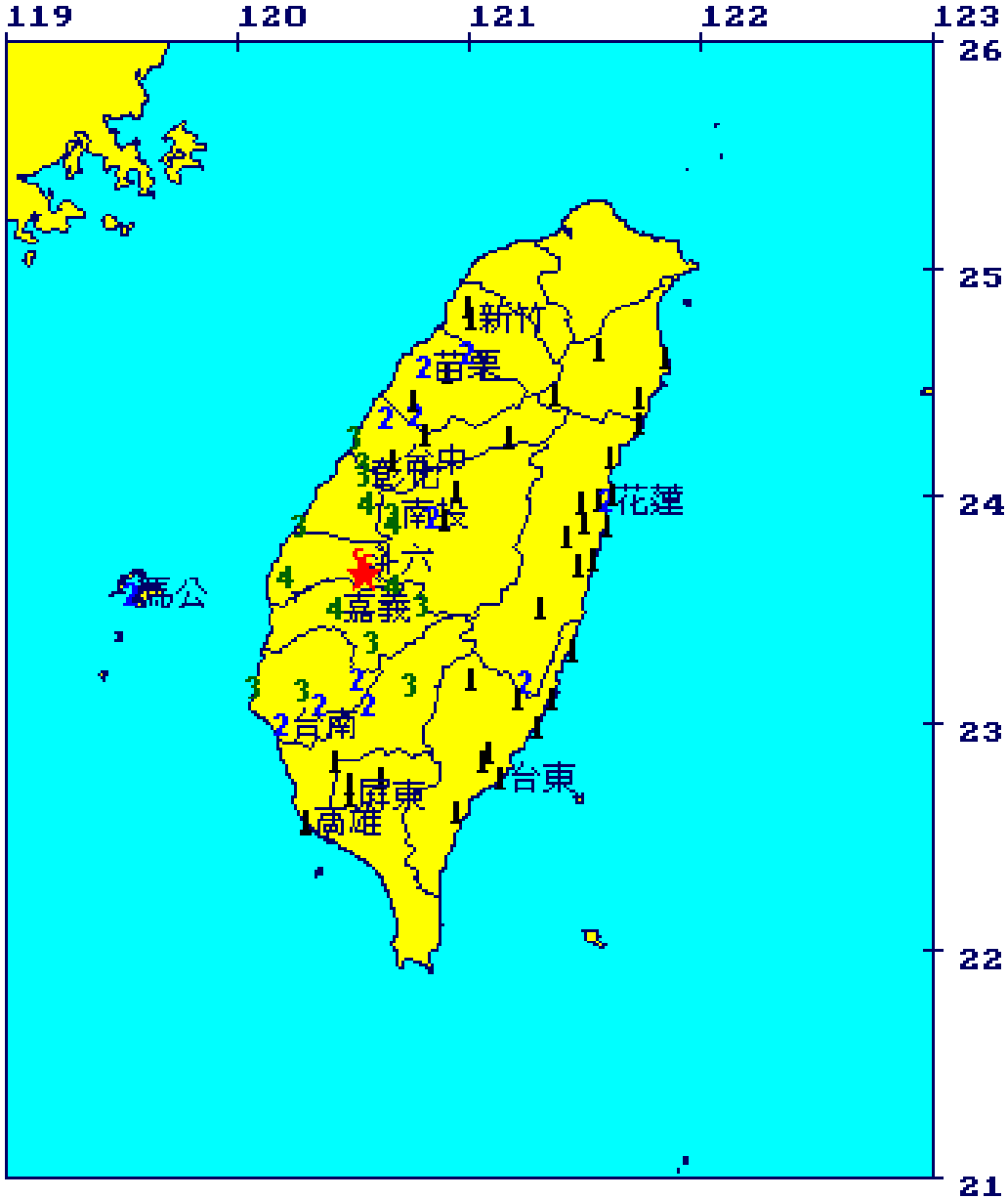
6. Institute of Geophysics, National Central University, Jhongli 320, Taiwan



中 央 氣 象 局 地 震 報 告

編號： 第95017號

日期： 95 年 3 月 9 日

時間： 12 時 7 分 28.8 秒

位置： 北緯 23.64 度，東經 120.56 度
即在 雲林古坑地震站南方 4.6 公里

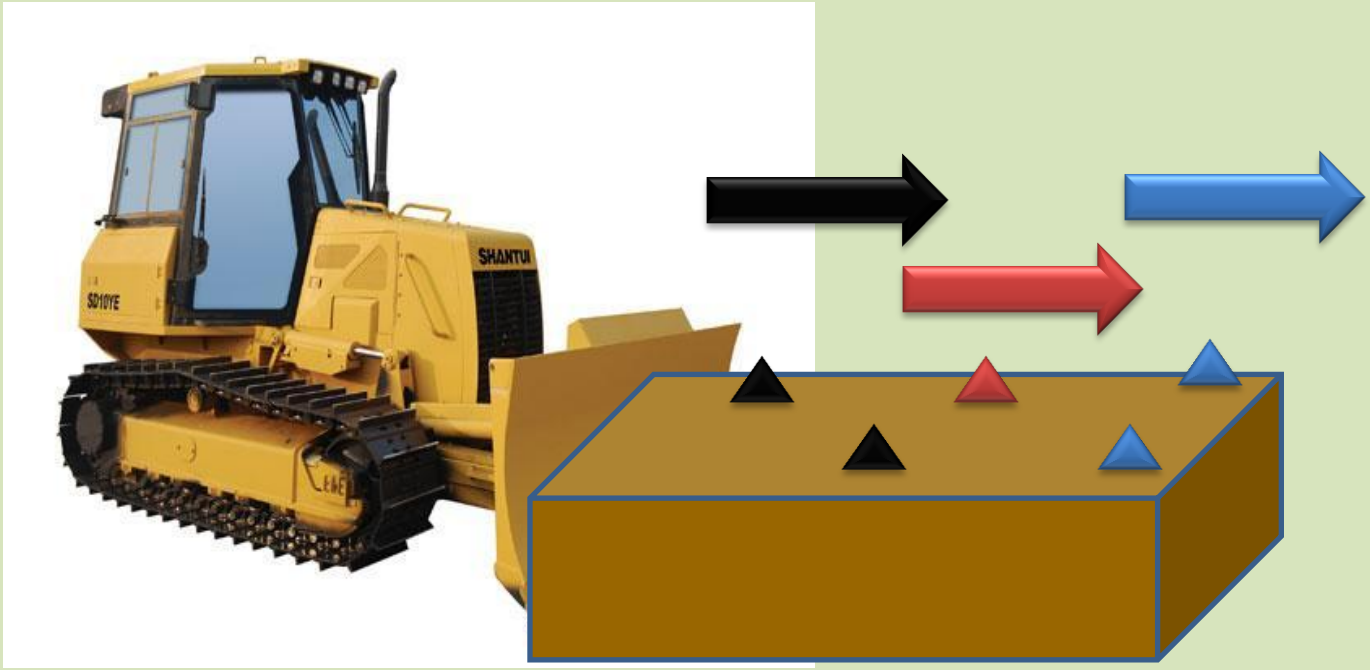
地震深度： 9.9 公里

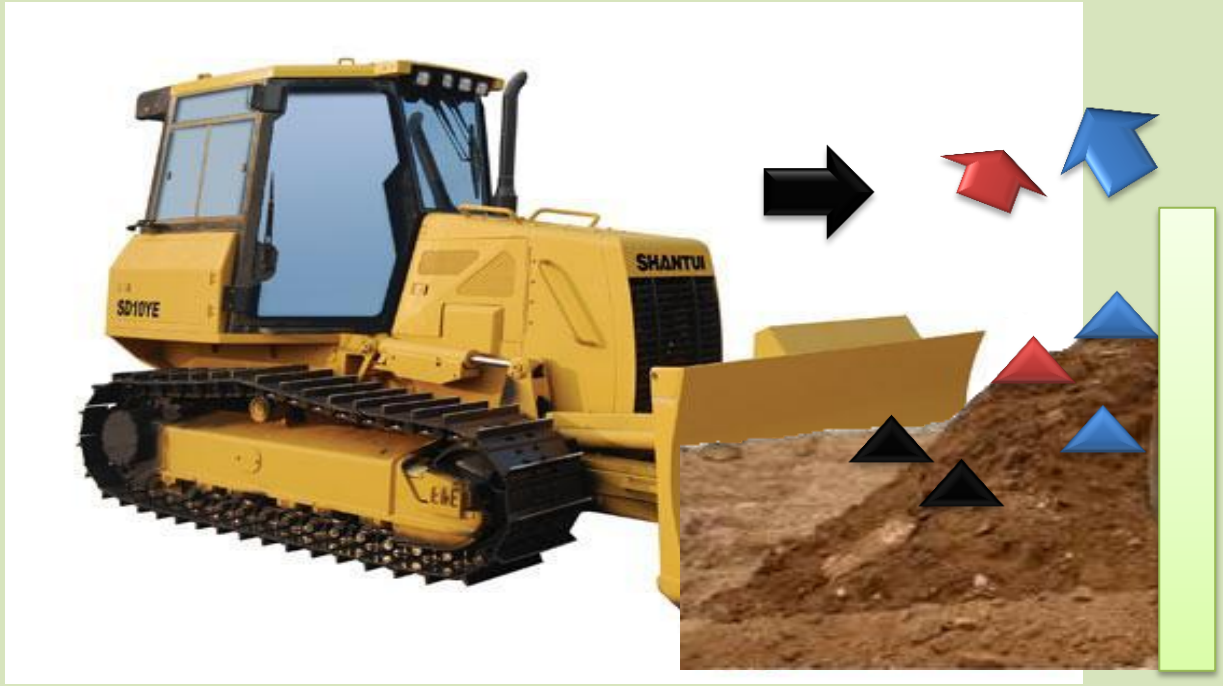
芮氏規模： 5.1

各地最大震度

雲林古坑	5級	花蓮市	2級
斗六市	5級	台中市	1級
嘉義市	4級	台東利稻	1級
南投名間	4級	屏東三地門	1級
彰化員林	4級	屏東市	1級
嘉義阿里山	3級	台東市	1級
南投市	3級	宜蘭南山	1級
彰化市	3級	高雄市	1級
台中大肚	3級	新竹市	1級
高雄桃源	3級	新竹竹北	1級
台南善化	3級		
苗栗鯉魚潭	2級		
台南市	2級		
花蓮富里	2級		
澎湖馬公	2級		
苗栗市	2級		

圖說：★表震央位置，阿拉伯數字表示該測站震度


SHANTUI
SD10YE


SHANTUI
SD10YE

Comparisons among the FFT、WT and HT

	Fourier	Wavelet	Hilbert-Huang
Basis	A priori	A prior	Adaptive
Frequency	Global uncertainty	Regional uncertainty	Local uncertainty
Presentation	Energy-frequency	Energy-time-frequency	Energy-time-frequency
Nonlinear	No	No	Yes
Non-stationary	No	Yes	Yes
Feature Extraction	No	discrete : No Continuous : Yes	Yes
Theoretical base	Theory complete	Theory complete	empirical

Hilbert-Huang Transform (HHT)

$x(t)$: *real time series*

$$y(t)=\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{x(\tau)}{t-\tau}d\tau \ (\textit{Hilbert Transform})$$

Instantaneous Amplitude & Frequency

- **Analytic signal**

$$z(t)=x(t)+jy(t)=m(t)e^{j\theta(t)}$$

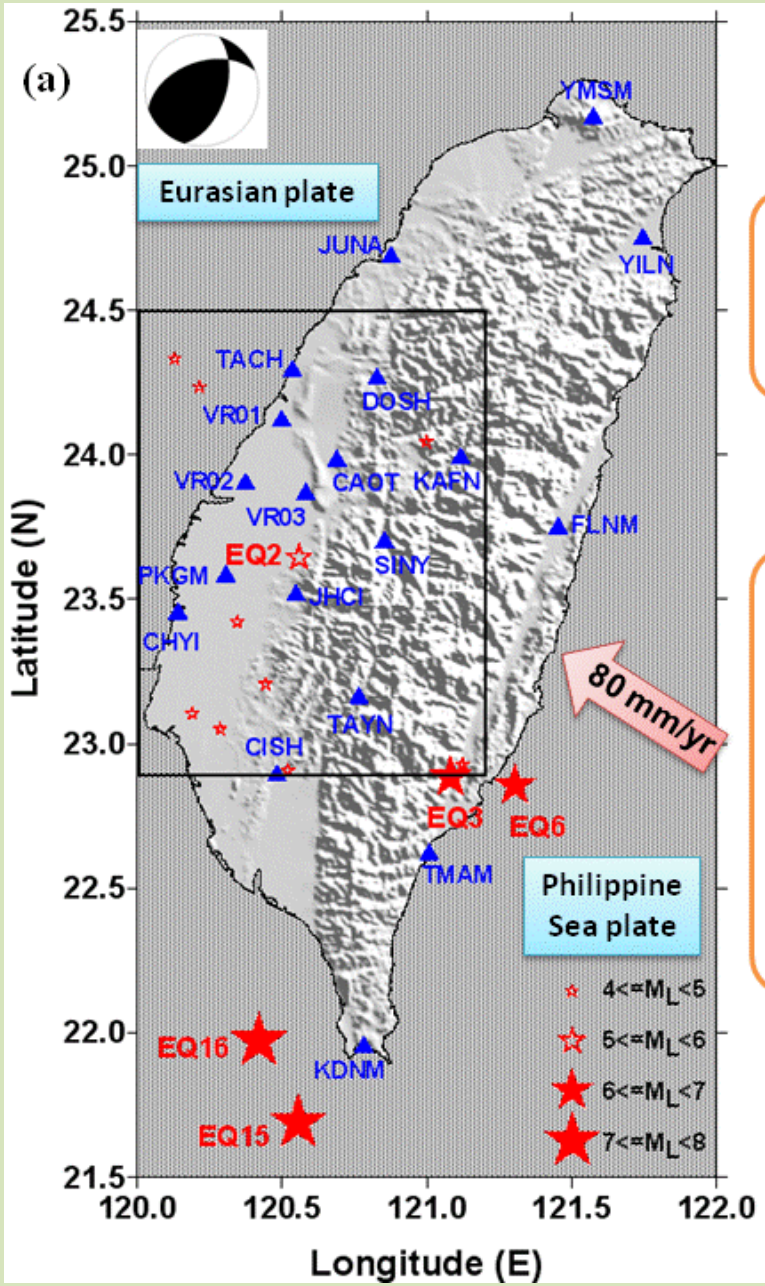
- **Instantaneous Amplitude & Phase**

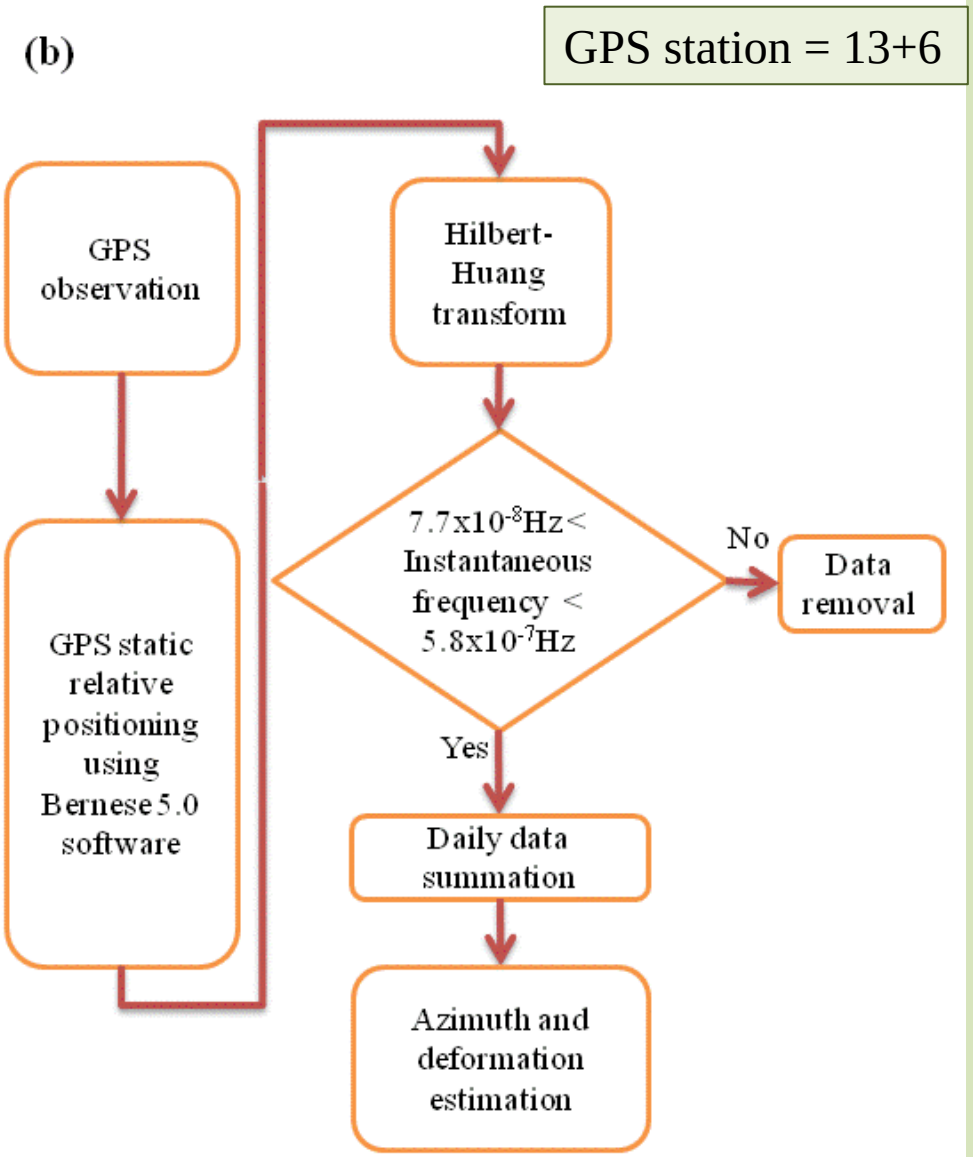
$$m(t)=\sqrt{x^2(t)+y^2(t)},\quad \theta(t)=\arctan\left(\frac{y(t)}{x(t)}\right)$$

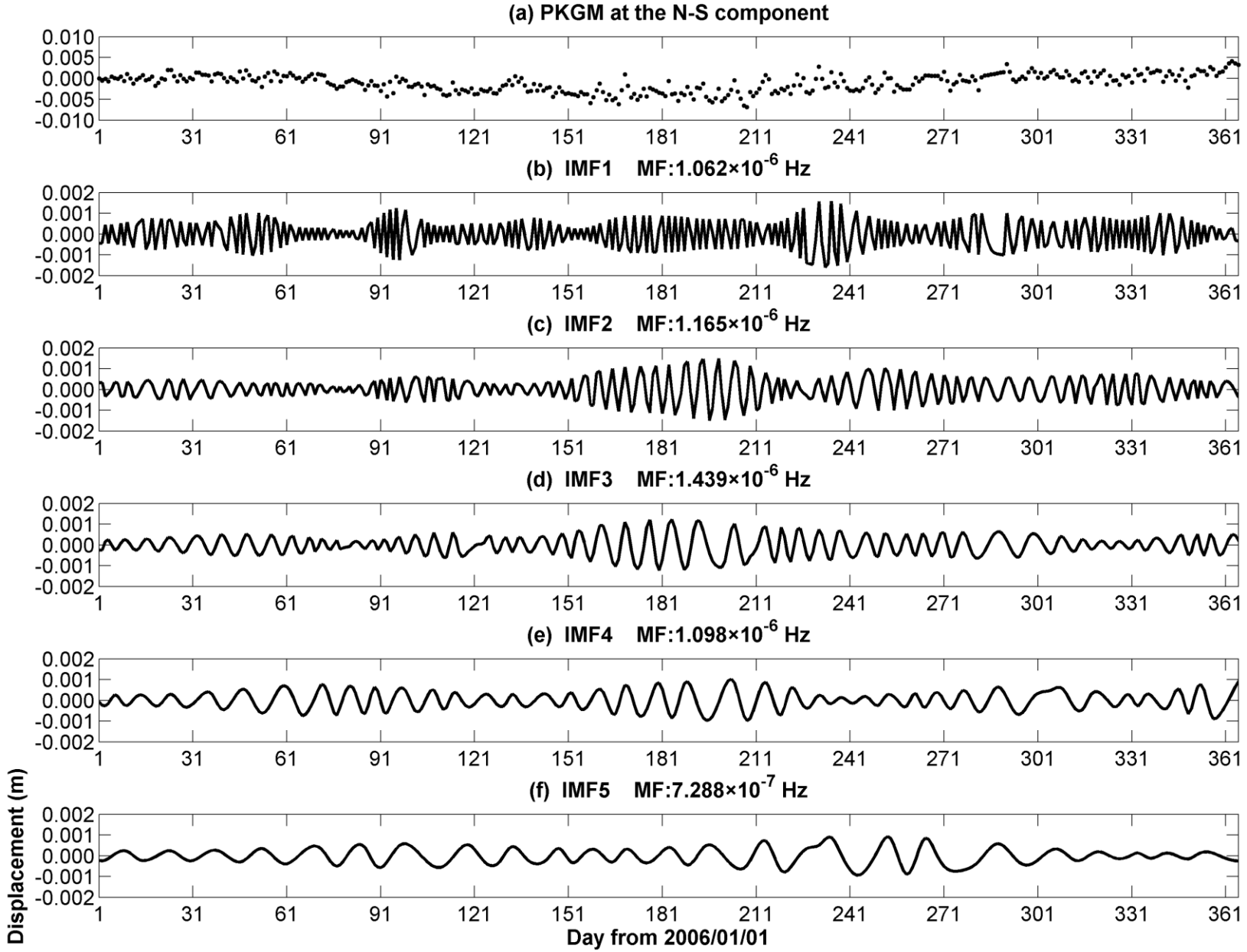
- **Instantaneous Frequency**

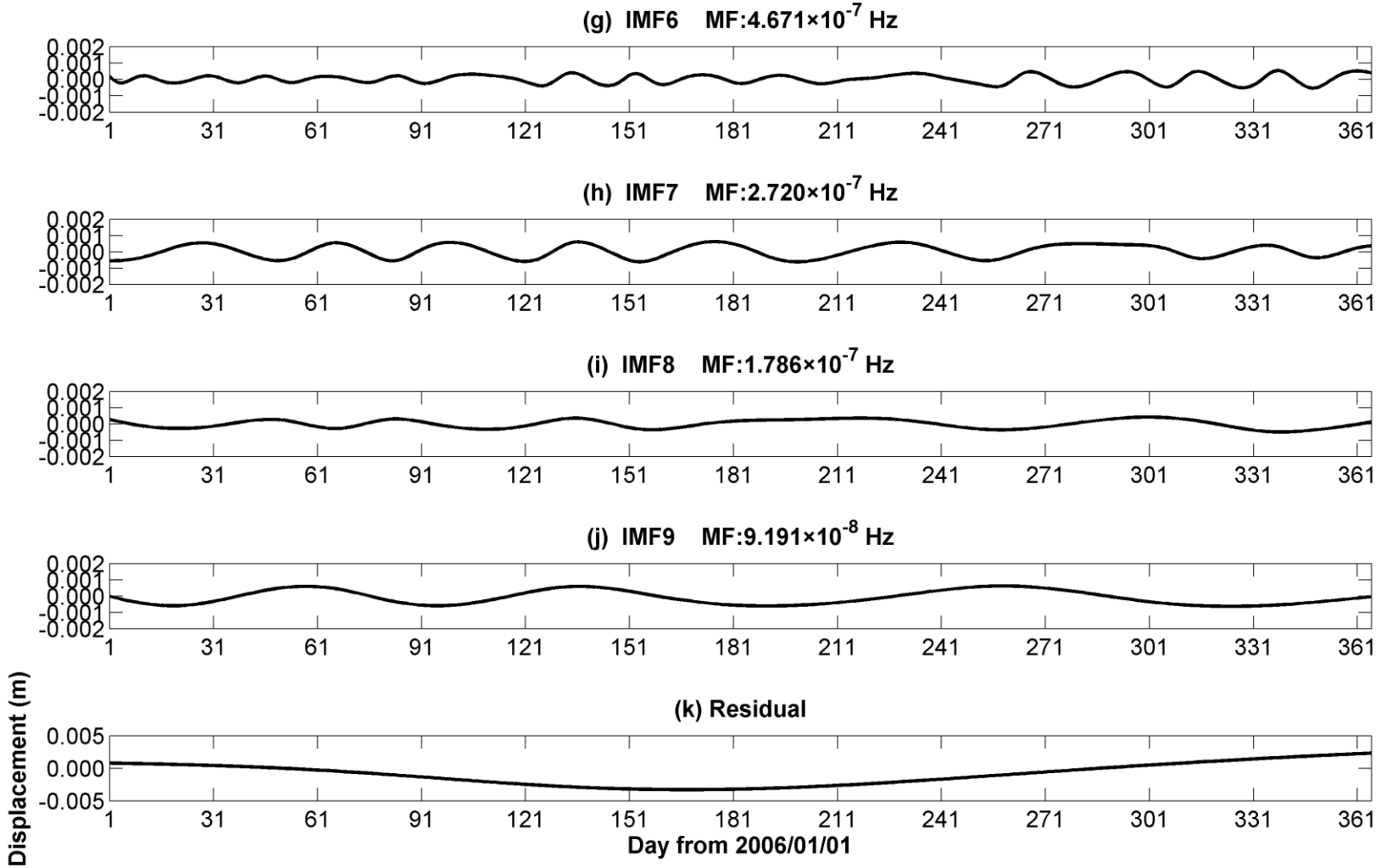
$$F(t)=\frac{d\theta(t)}{dt}$$

Data Analyses



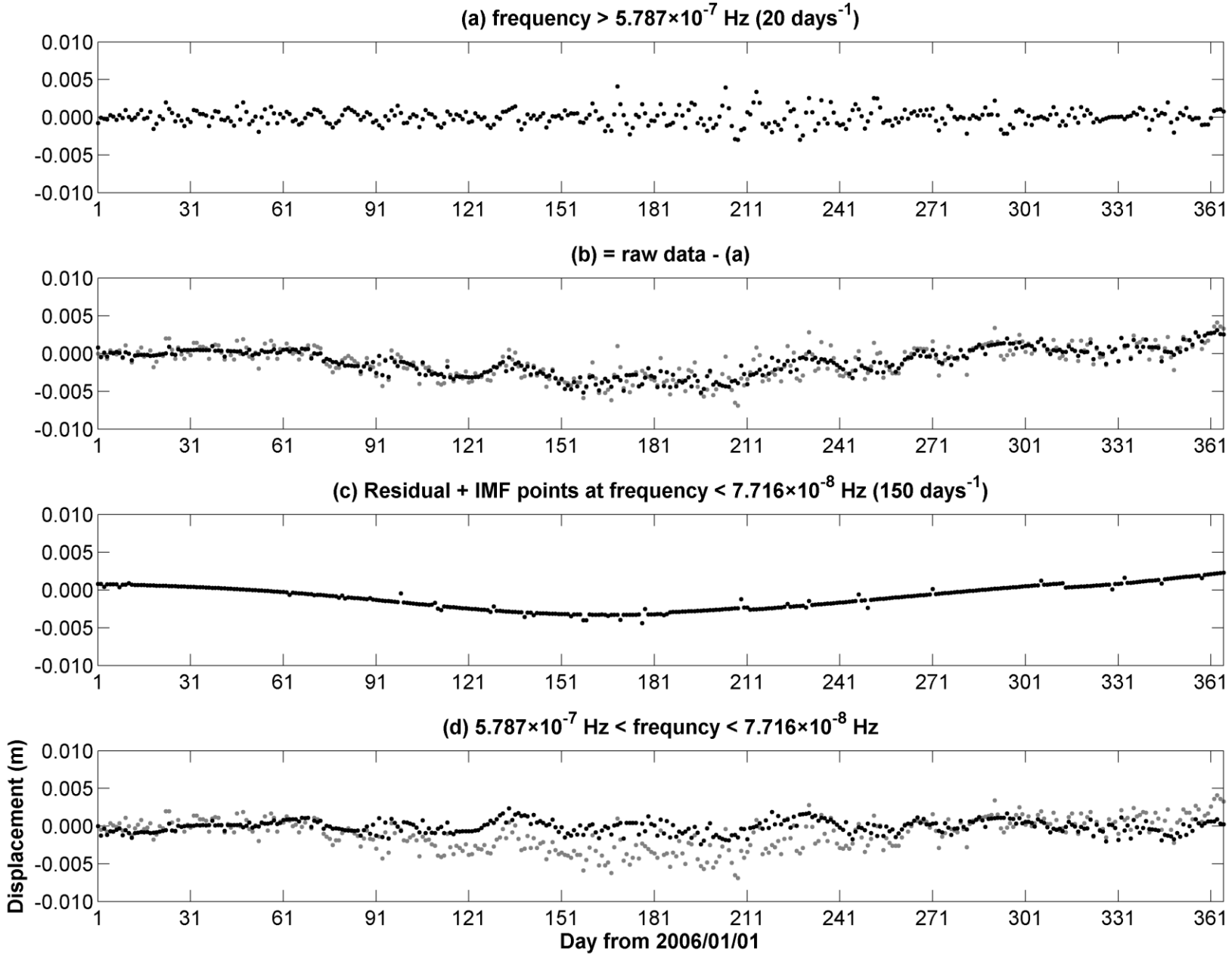



(a) PKGM at the N-S component
0.010
0.005
0.000
-0.005
-0.010
1 31 61 91 121 151 181 211 241 271 301 331 361
(b) IMF1 MF:1.062×10-6 Hz
0.002
0.001
0.000
-0.001
-0.002
1 31 61 91 121 151 181 211 241 271 301 331 361
(c) IMF2 MF:1.165×10-6 Hz
0.002
0.001
0.000
-0.001
-0.002
1 31 61 91 121 151 181 211 241 271 301 331 361
(d) IMF3 MF:1.439×10-6 Hz
0.002
0.001
0.000
-0.001
-0.002
1 31 61 91 121 151 181 211 241 271 301 331 361
(e) IMF4 MF:1.098×10-6 Hz
0.002
0.001
0.000
-0.001
-0.002
1 31 61 91 121 151 181 211 241 271 301 331 361
(f) IMF5 MF:7.288×10-7 Hz
0.002
0.001
0.000
-0.001
-0.002
1 31 61 91 121 151 181 211 241 271 301 331 361
Displacement (m)
Day from 2006/01/01

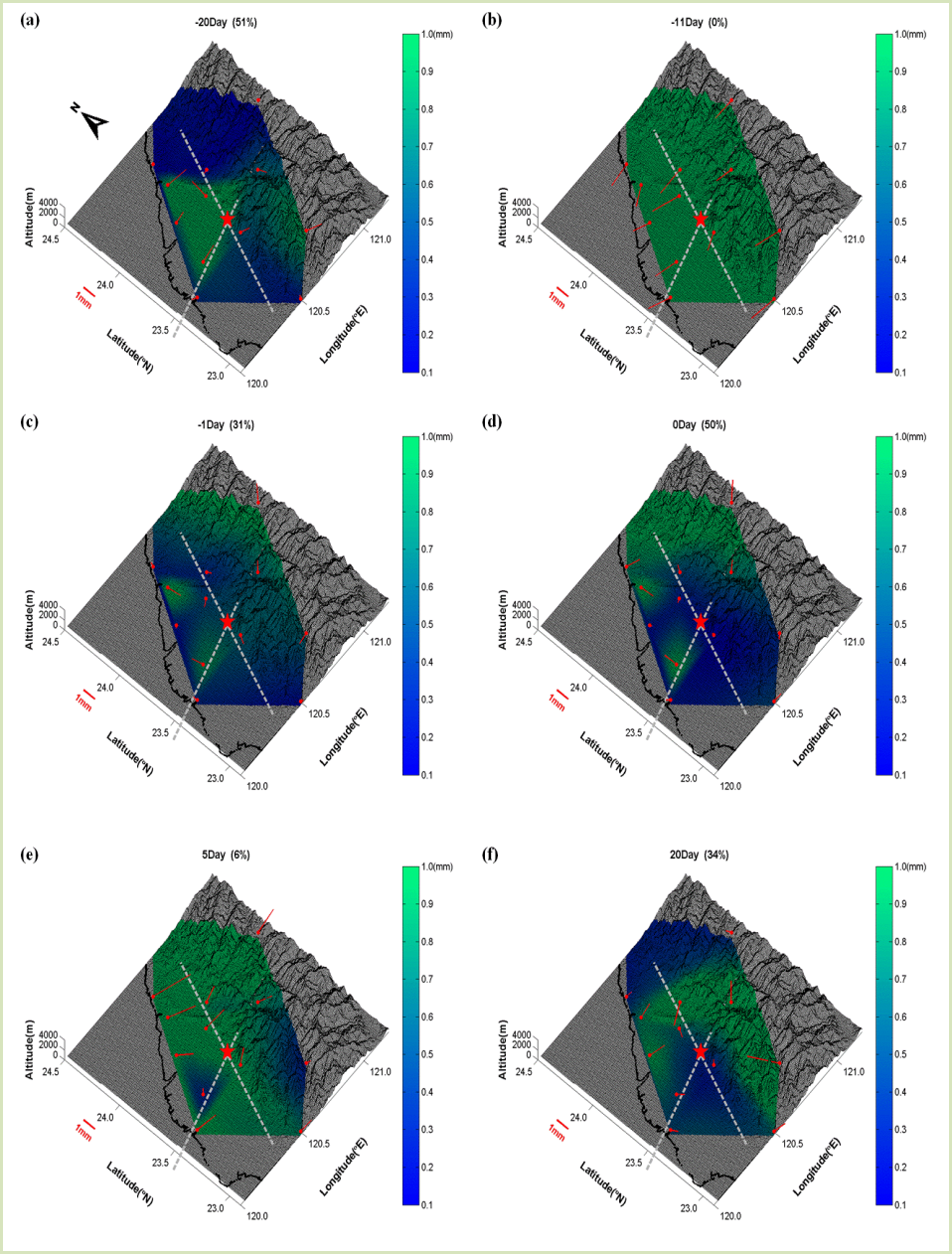

(g) IMF6 MF:4.671×10-7 Hz
(h) IMF7 MF:2.720×10-7 Hz
(i) IMF8 MF:1.786×10-7 Hz
(j) IMF9 MF:9.191×10-8 Hz
(k) Residual
Displacement (m)
Day from 2006/01/01
0.002
0.001
0.000
-0.001
-0.002
0.005
0.000
-0.005
1
31
61
91
121
151
181
211
241
271
301
331
361

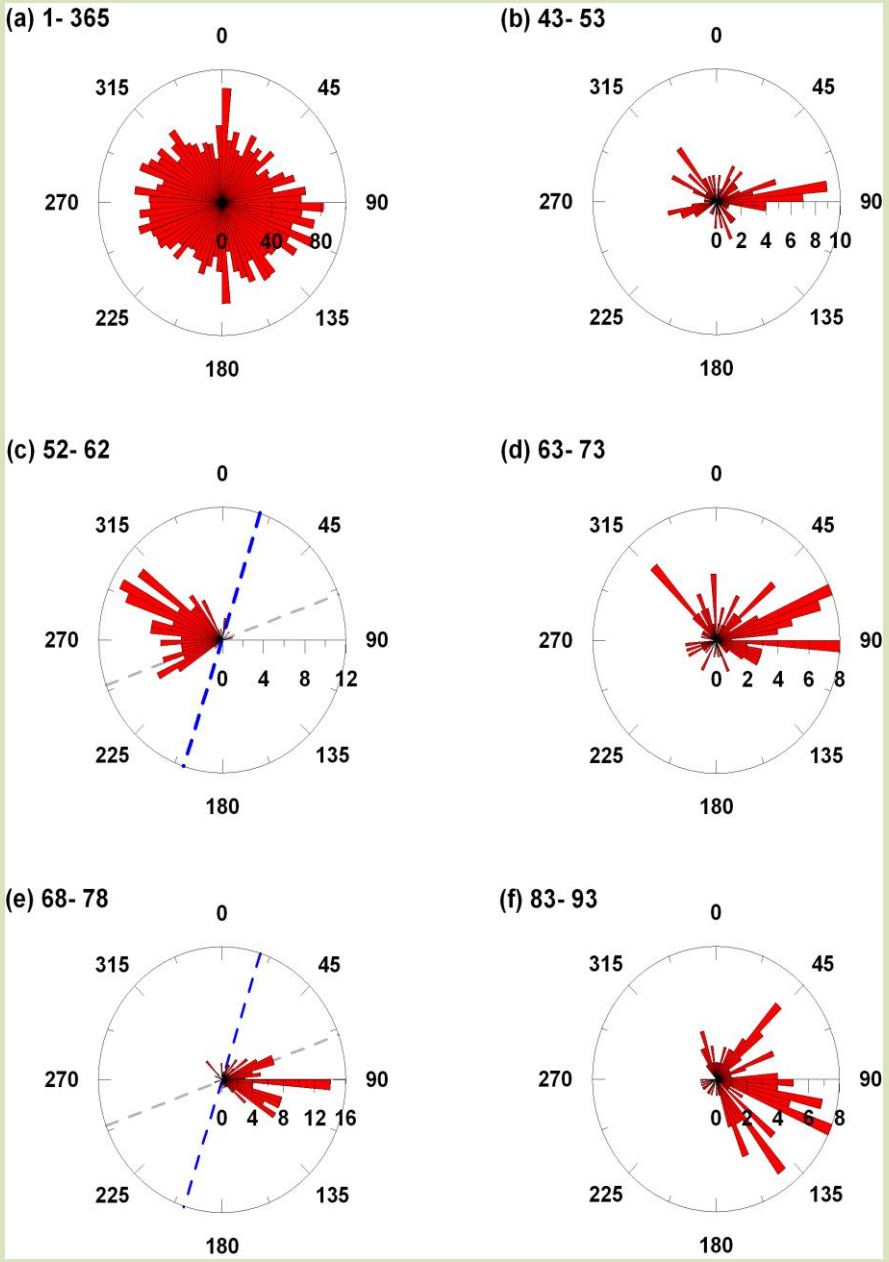
Median frequency and period of the IMFs in the NS component of PKGM station

IMFs	Median Frequency (Hz)	Median Period (day)
1	1.062×10^{-6}	10.9
2	1.165×10^{-6}	9.94
3	1.439×10^{-6}	8.04
4	1.098×10^{-6}	10.5
5	7.288×10^{-7}	15.9
6	4.671×10^{-7}	24.8
7	2.720×10^{-7}	42.5
8	1.786×10^{-7}	64.8
9	9.191×10^{-8}	125.9

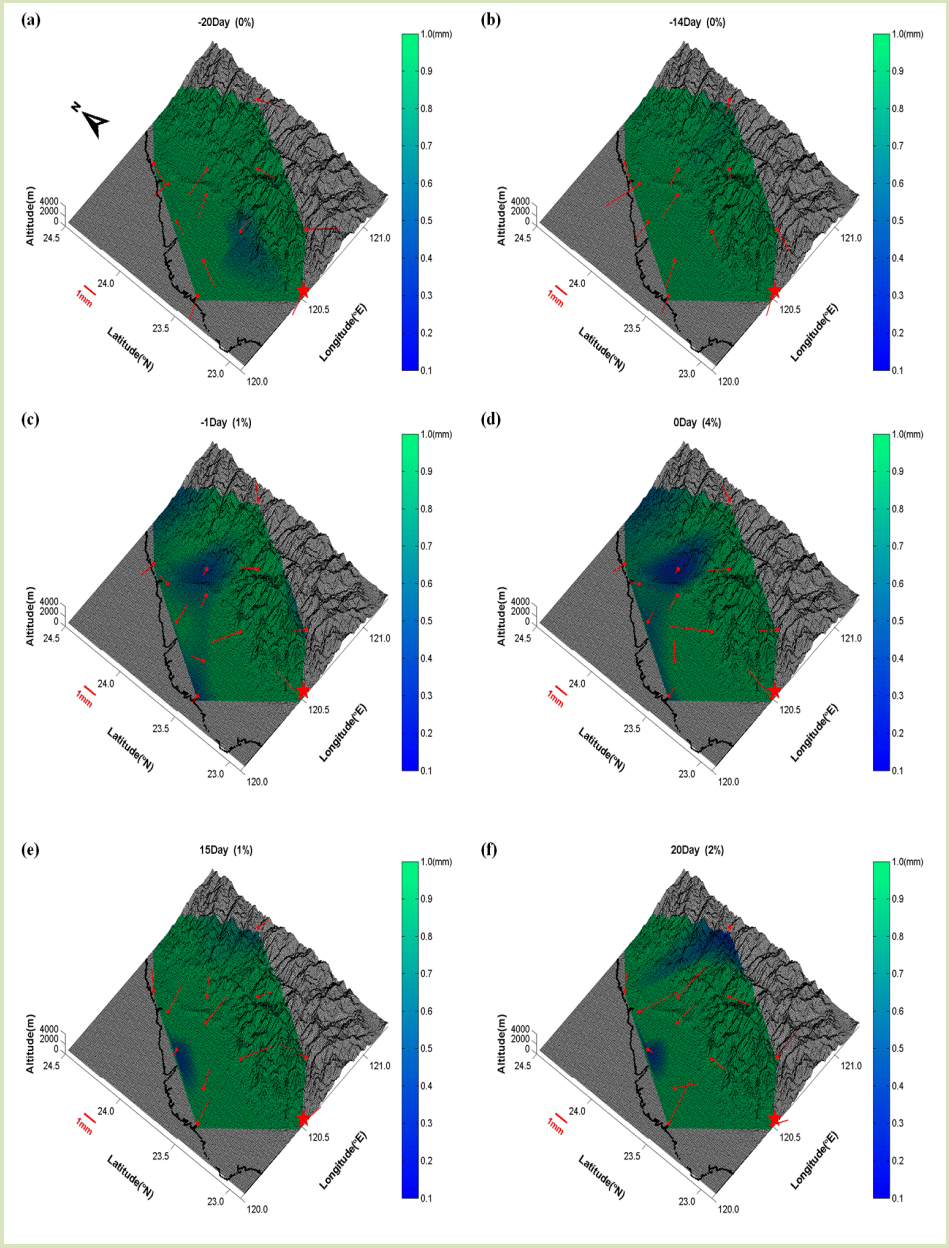

(a) frequency > 5.787×10-7 Hz (20 days-1)
(b) = raw data - (a)
(c) Residual + IMF points at frequency < 7.716×10-8 Hz (150 days-1)
(d) 5.787×10-7 Hz < frequncy < 7.716×10-8 Hz
Displacement (m)
0.010
0.005
0.000
-0.005
-0.010
1
31
61
91
121
151
181
211
241
271
301
331
361
Day from 2006/01/01

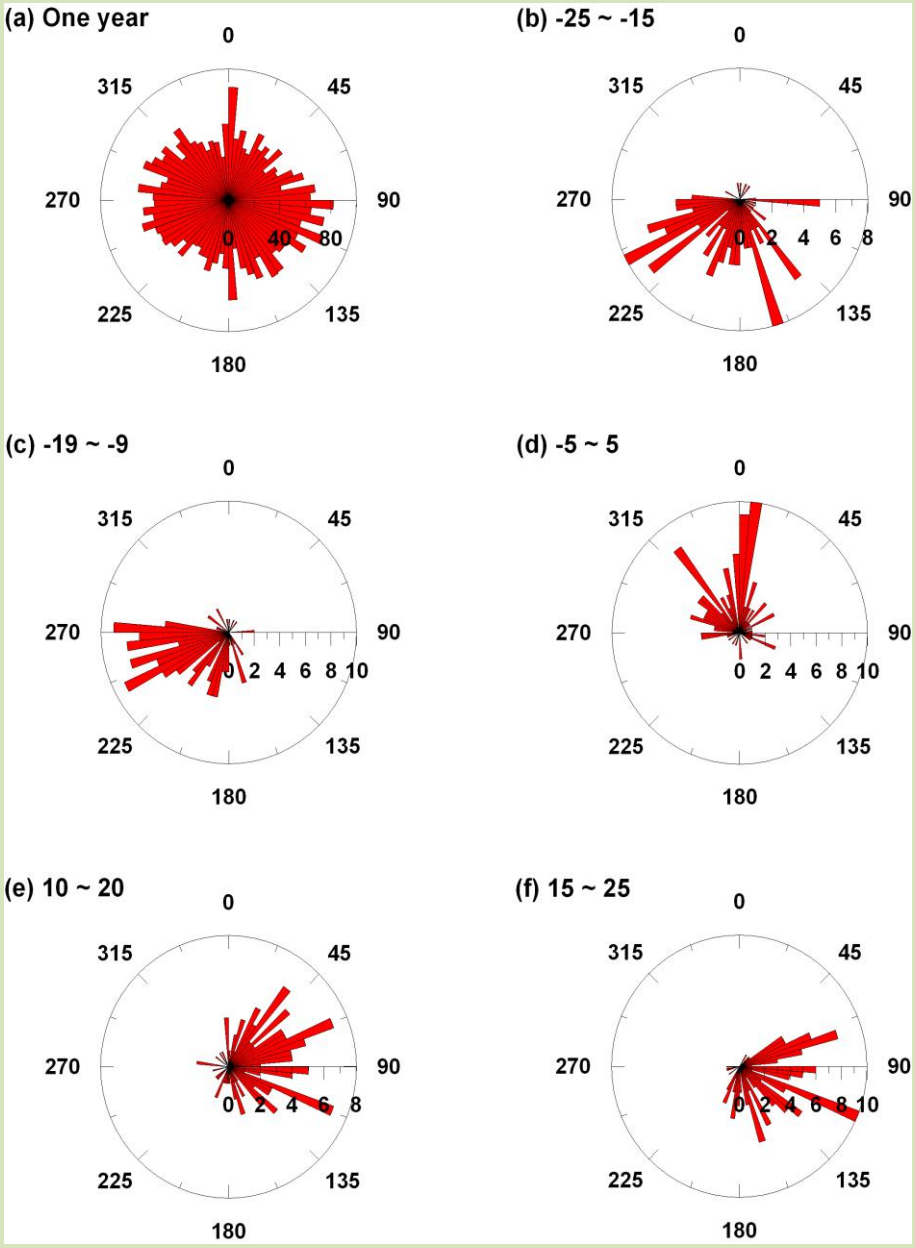
The GPS horizontal azimuths v.s. 雲林古坑地震(M=5.1)



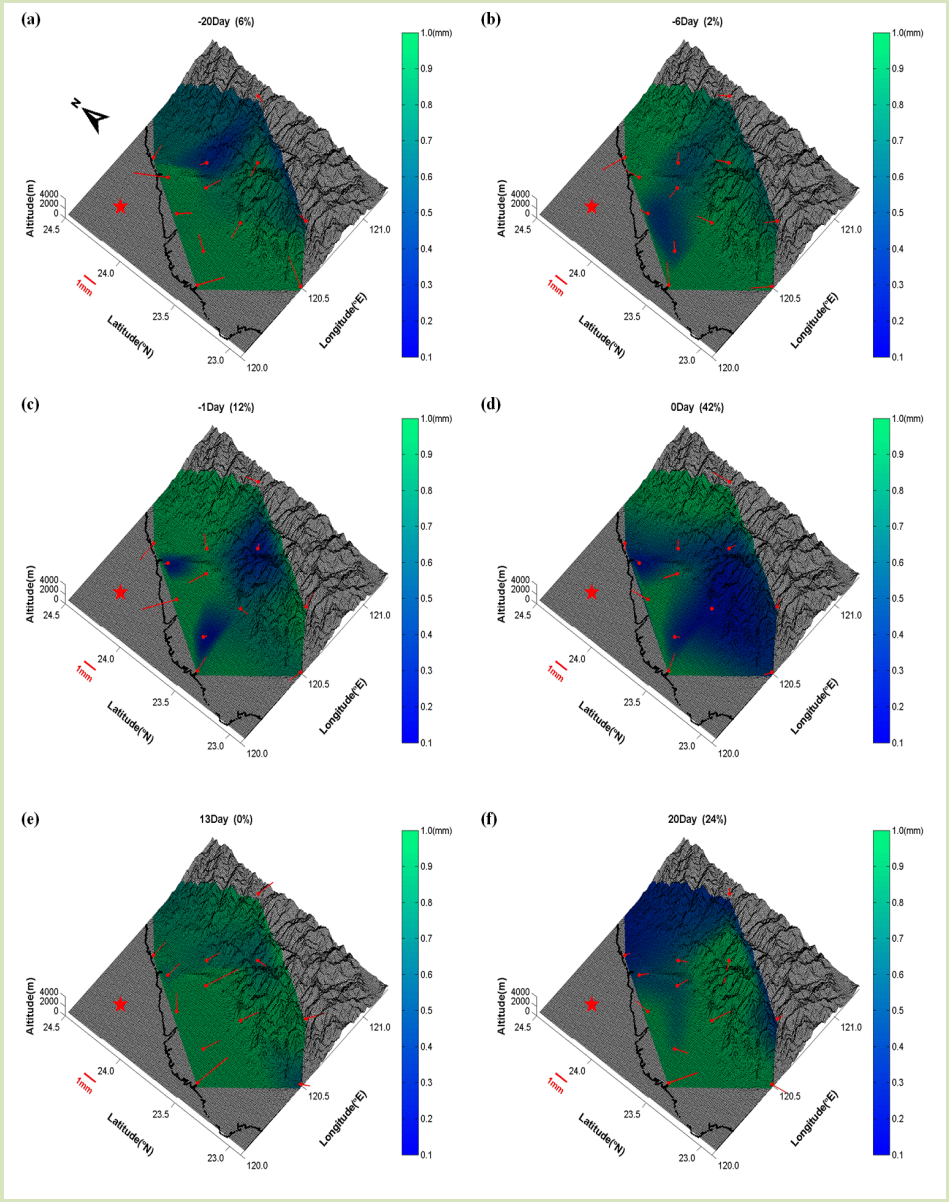


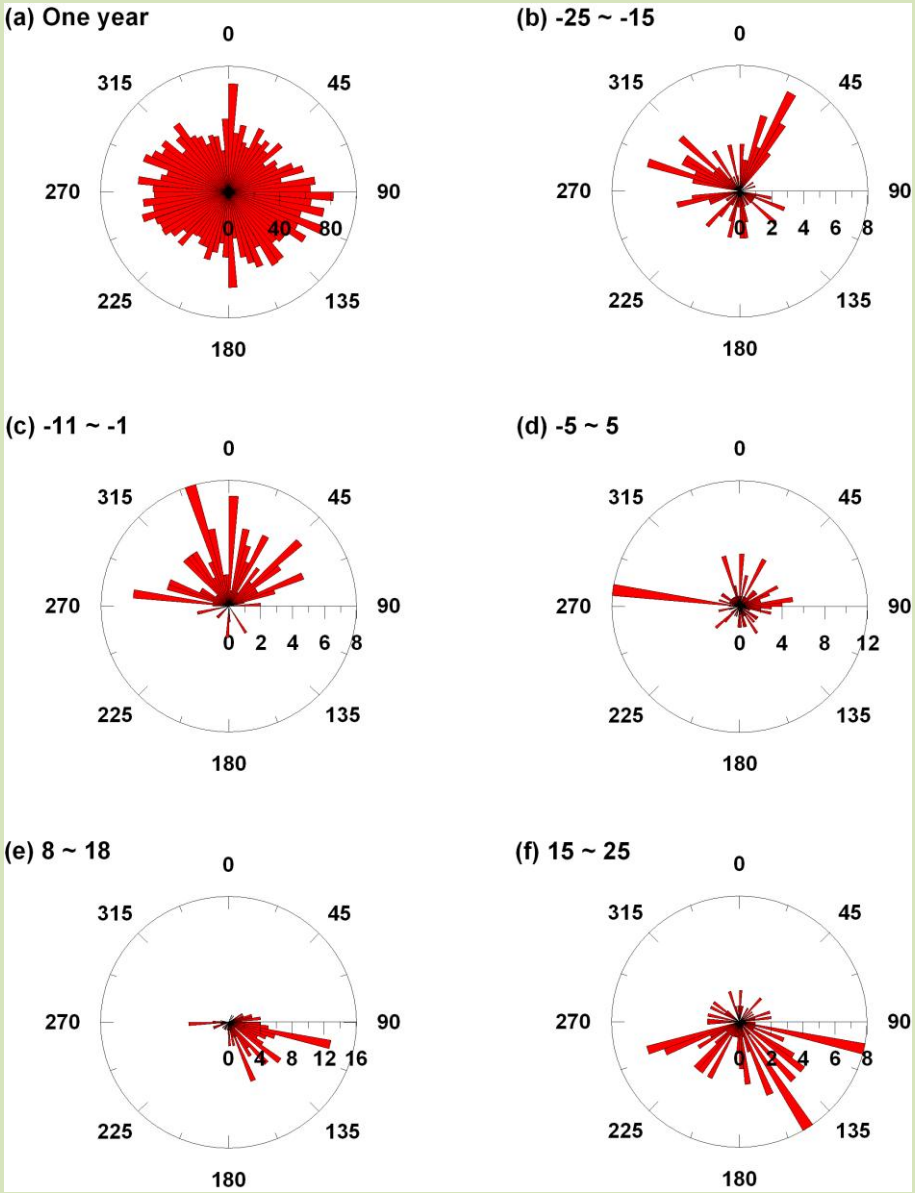
The GPS horizontal azimuths v.s. EQ224 (M=4.1)



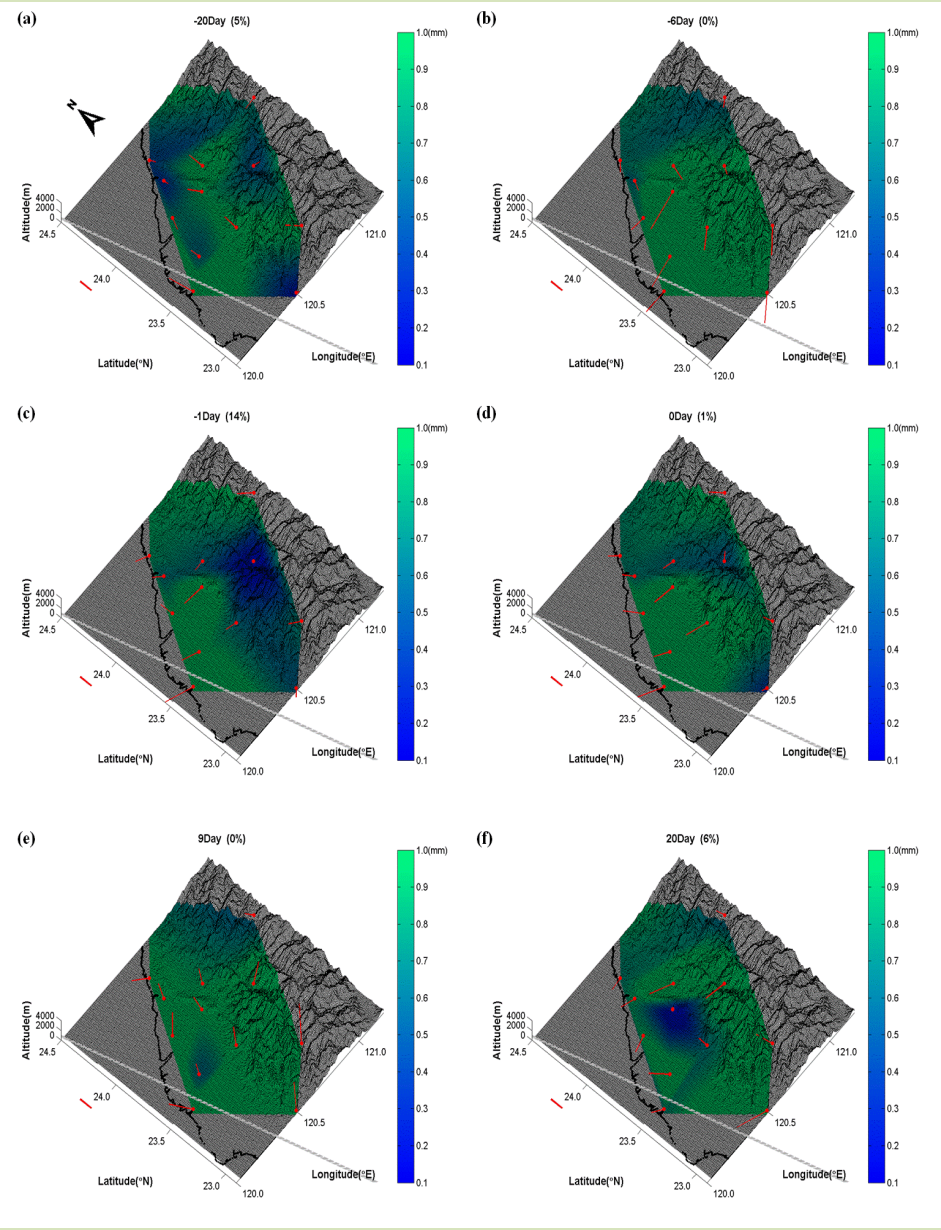


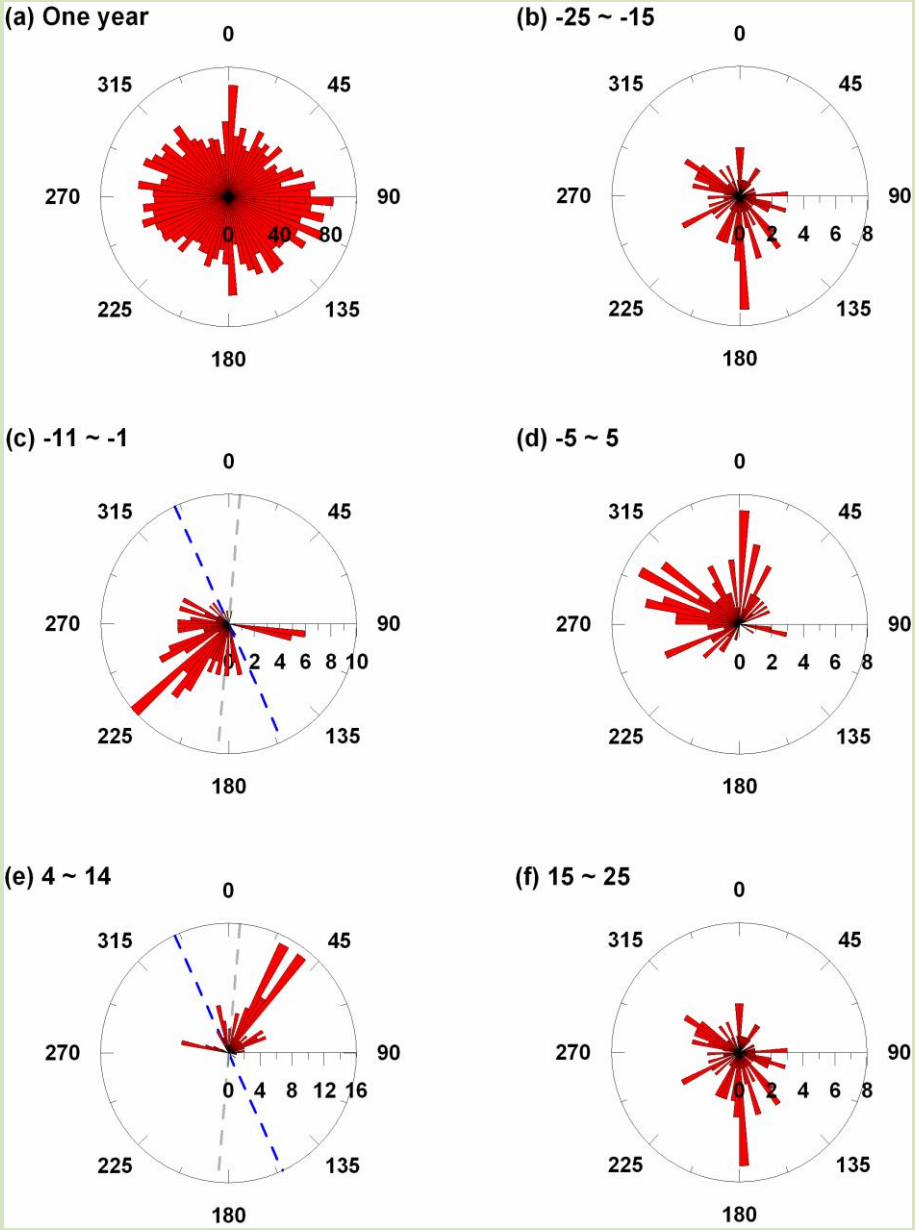
The GPS horizontal azimuths v.s. EQ310 (M=4.2)



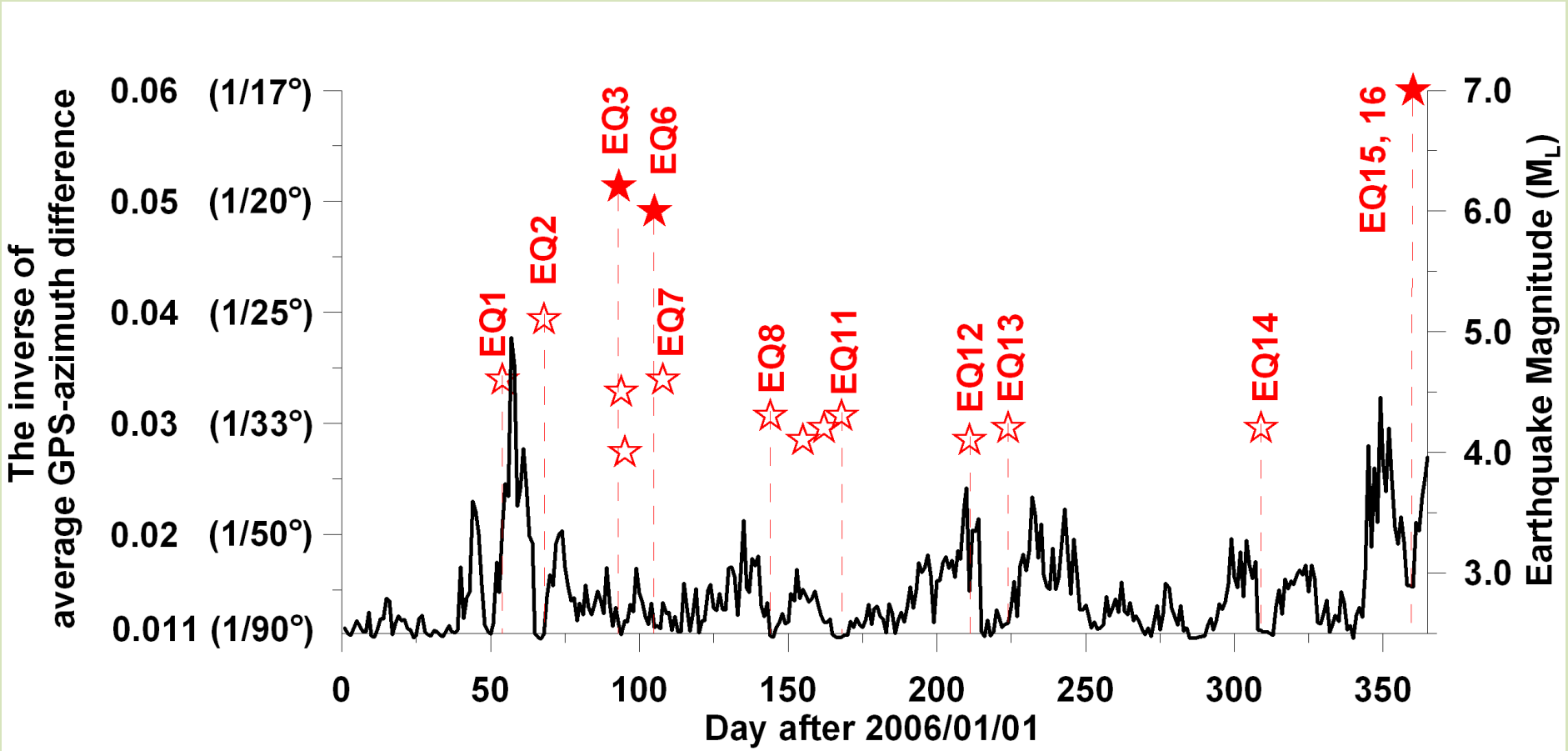


The GPS horizontal azimuths v.s.屏東地震 (M=7)





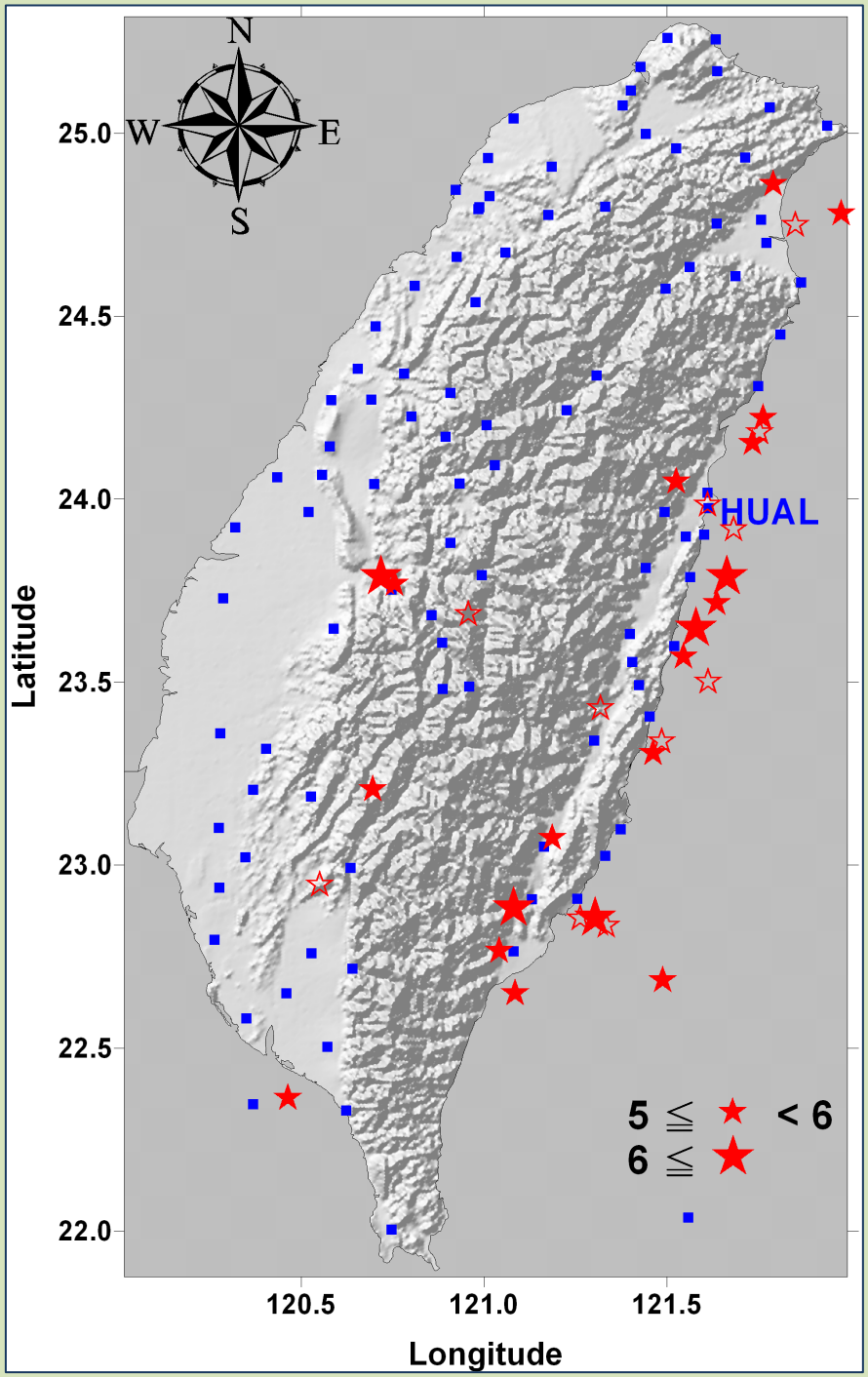
The inverse of average GPS-azimuth difference in 2006

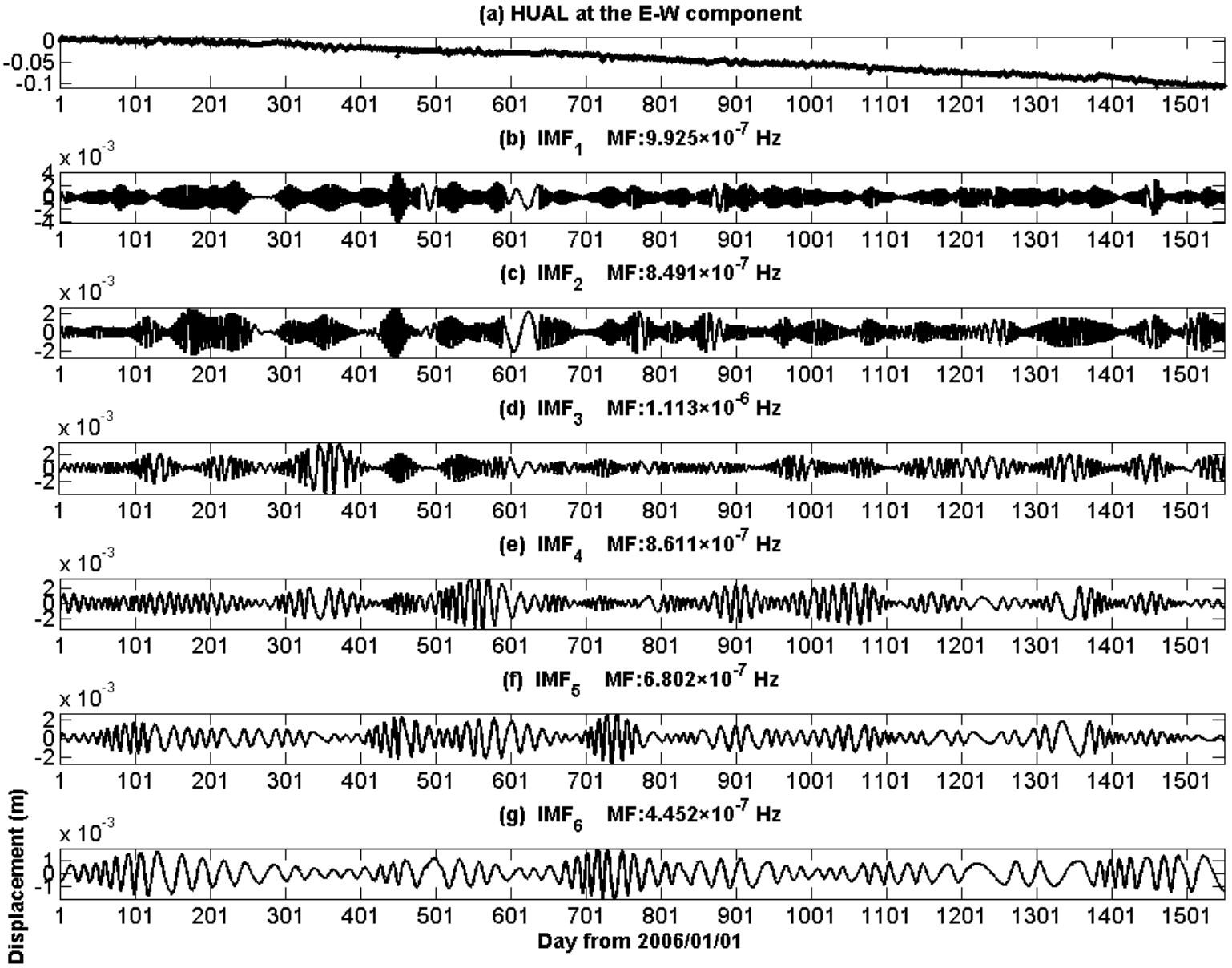


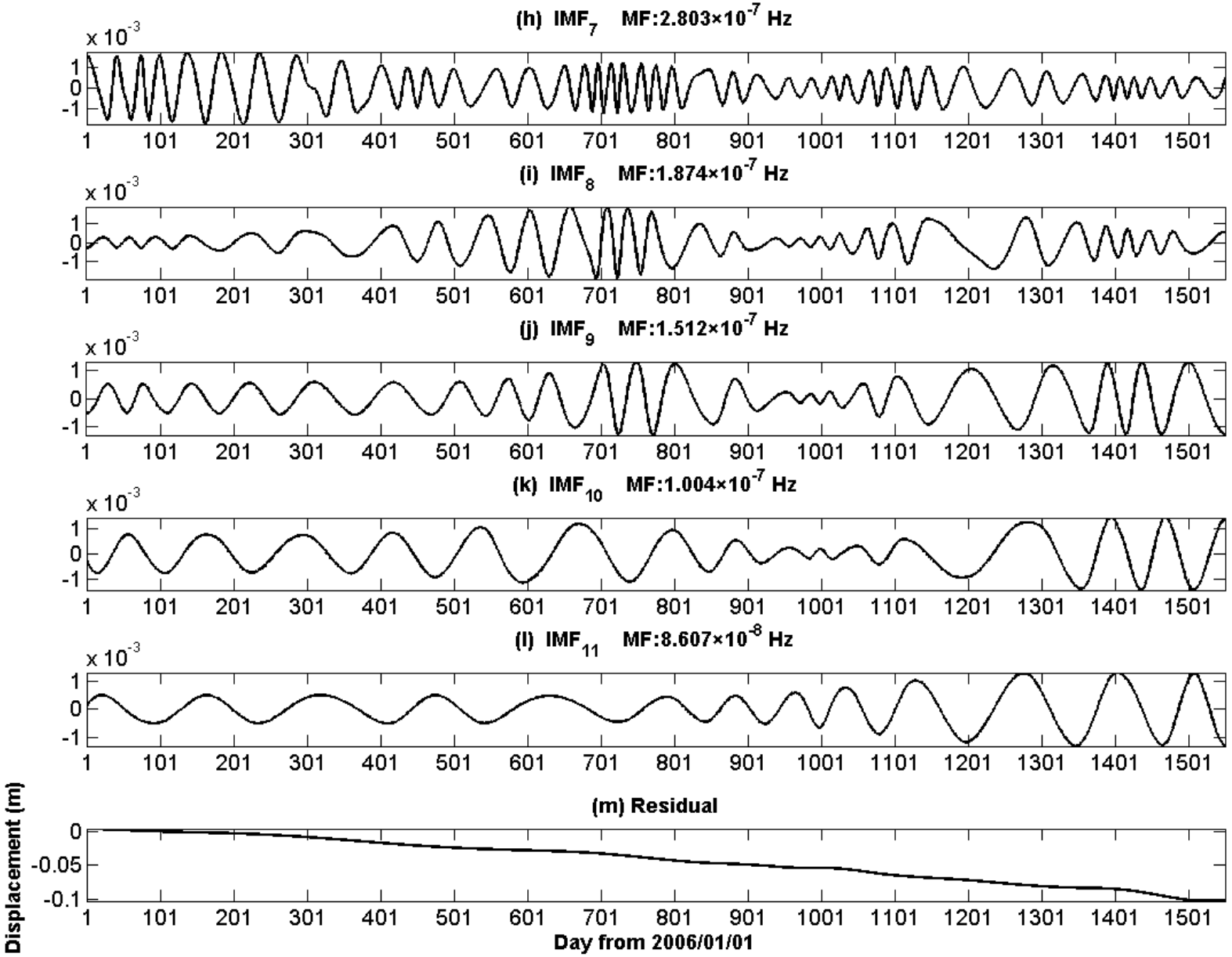
2006-2009

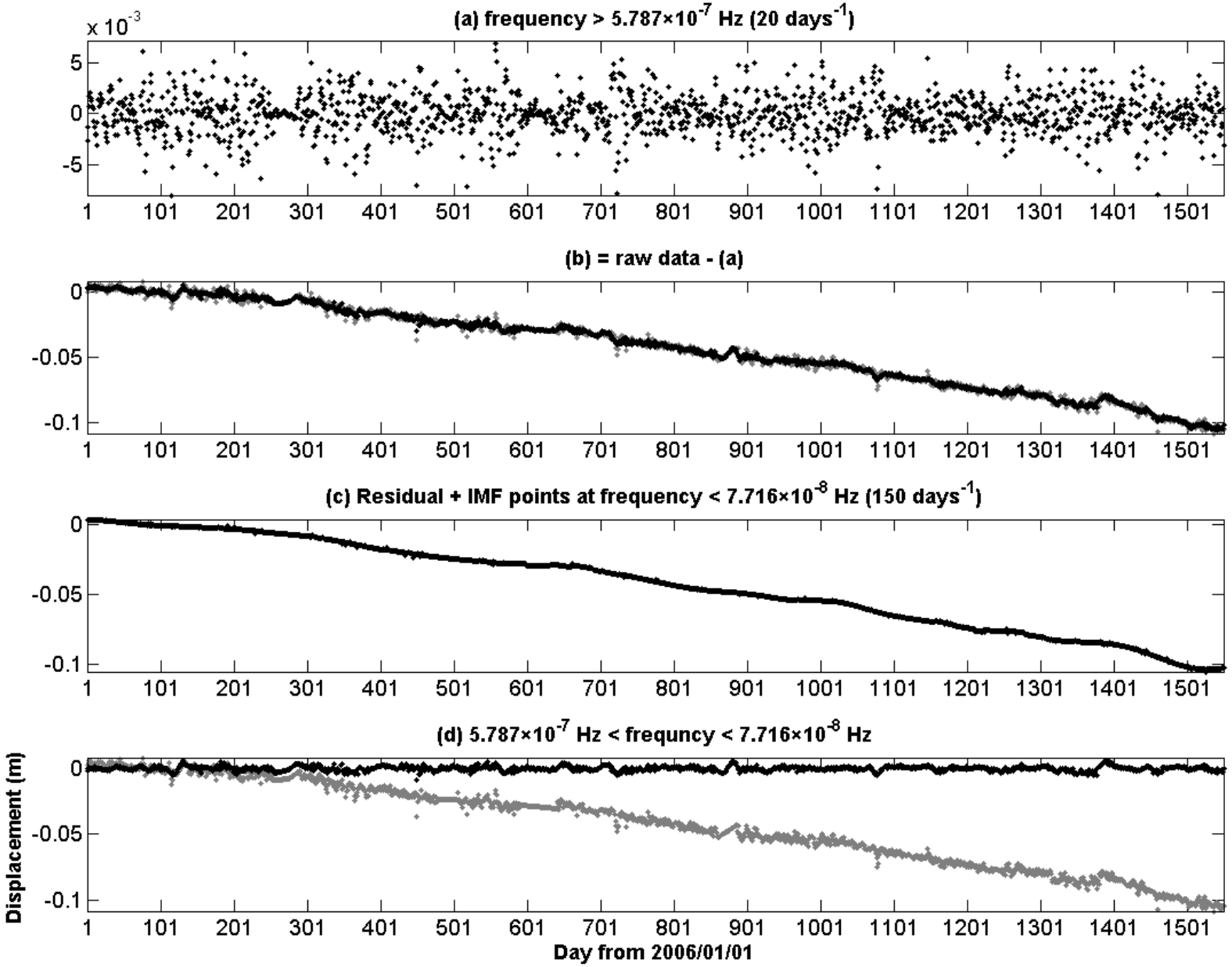
GPS =
99 stations

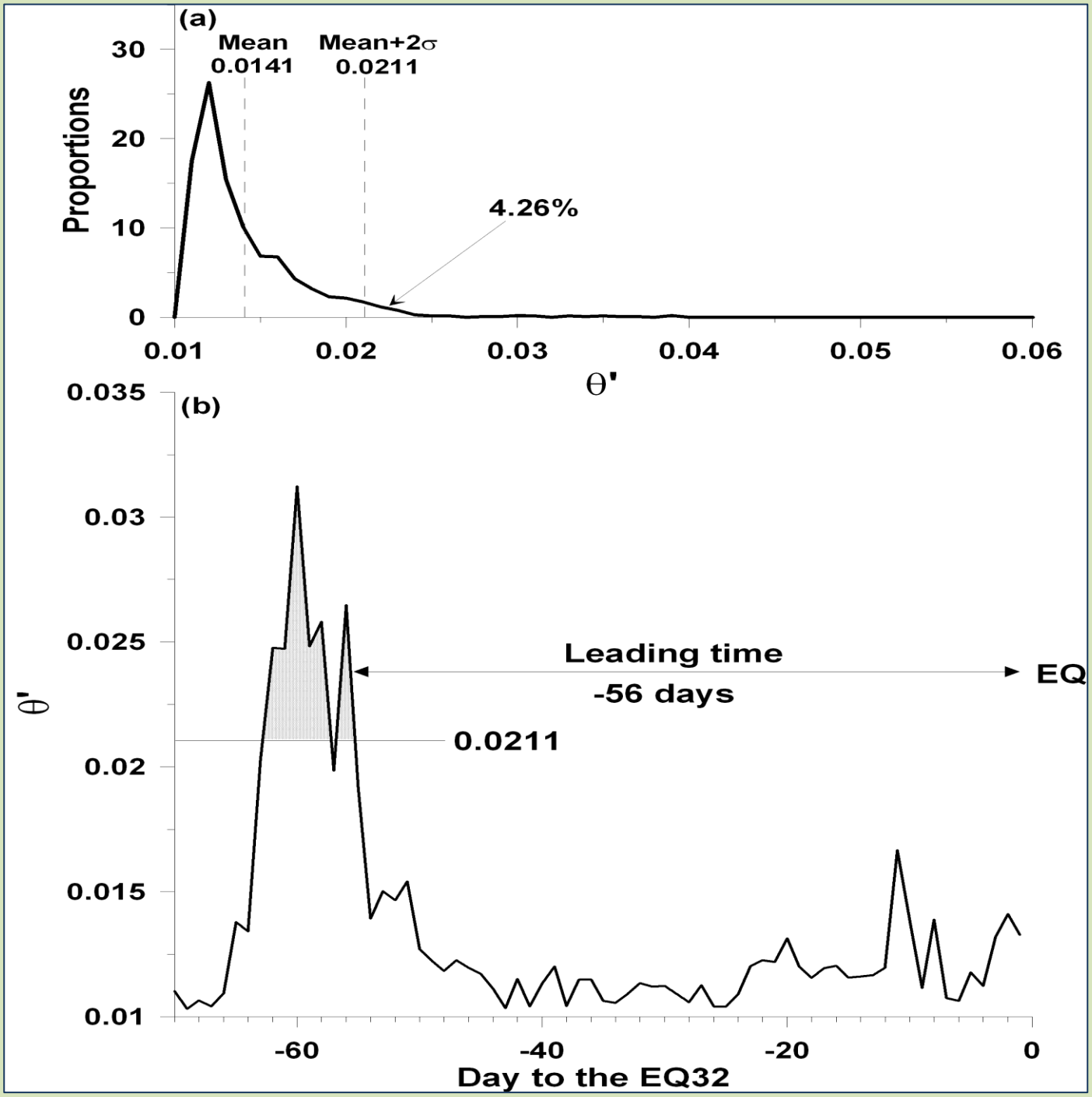
Earthquakes
= 32

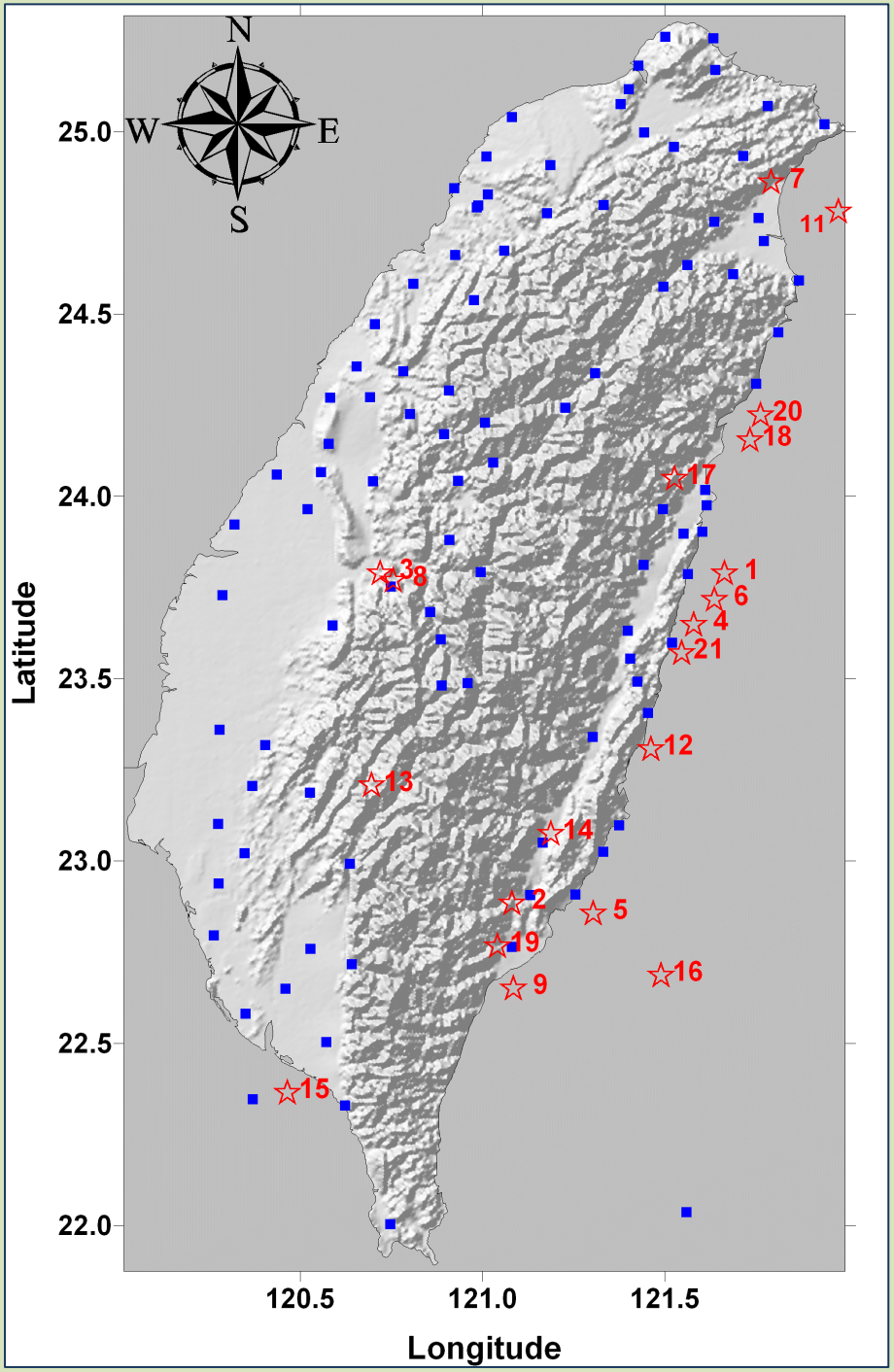



(a) HUAL at the E-W component
0
-0.05
-0.1
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501
(b) IMF1 MF:9.925×10-7 Hz
x 10-3
4
2
0
-2
-4
(c) IMF2 MF:8.491×10-7 Hz
x 10-3
2
0
-2
(d) IMF3 MF:1.113×10-6 Hz
x 10-3
2
0
-2
(e) IMF4 MF:8.611×10-7 Hz
x 10-3
2
0
-2
(f) IMF5 MF:6.802×10-7 Hz
x 10-3
2
0
-2
(g) IMF6 MF:4.452×10-7 Hz
x 10-3
1
0
-1
Displacement (m)
Day from 2006/01/01

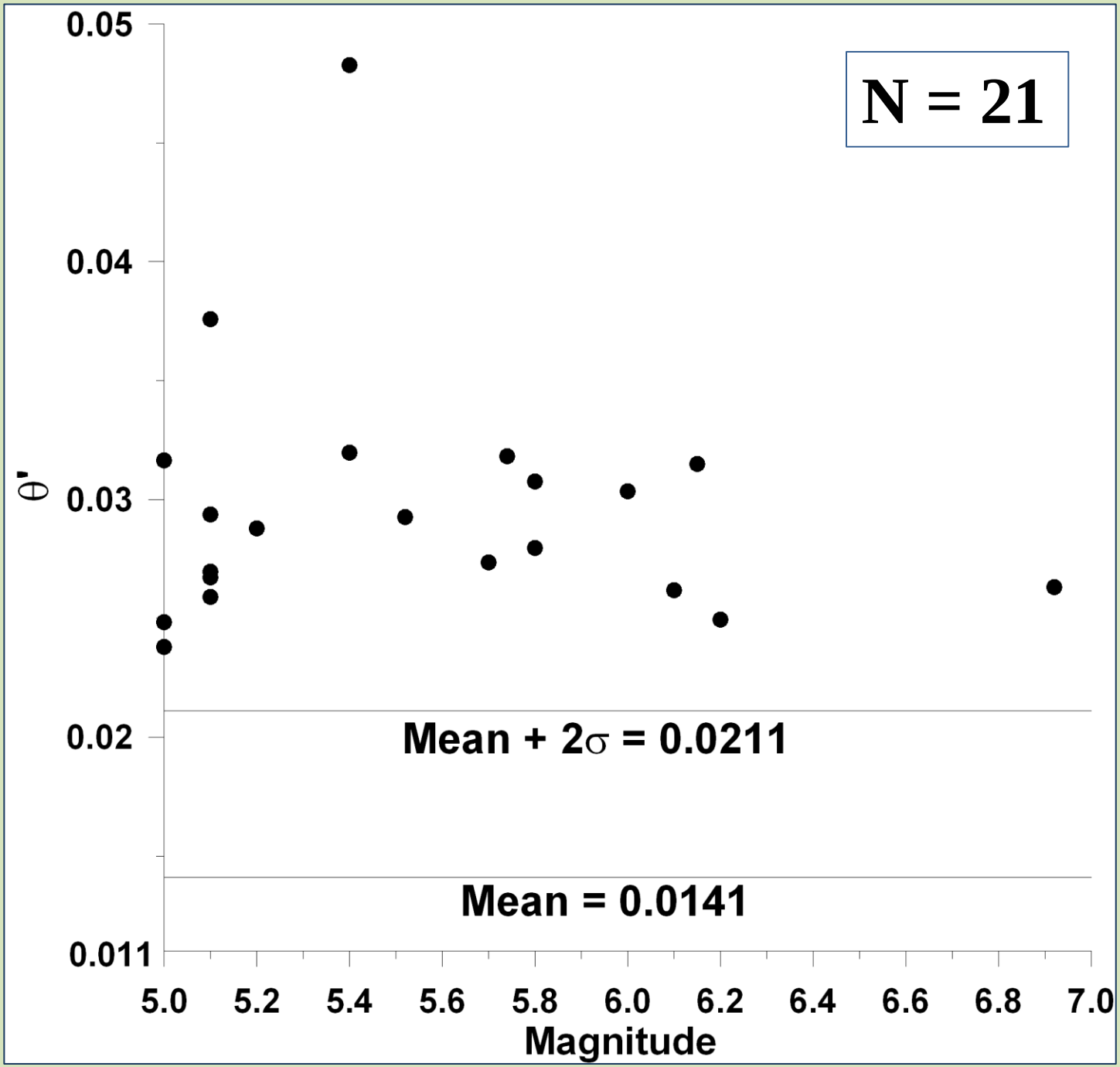

(h) IMF7 MF:2.803×10-7 Hz
(i) IMF8 MF:1.874×10-7 Hz
(j) IMF9 MF:1.512×10-7 Hz
(k) IMF10 MF:1.004×10-7 Hz
(l) IMF11 MF:8.607×10-8 Hz
(m) Residual
x 10-3
1
0
-1
0
-0.05
-0.1
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501
Displacement (m)
Day from 2006/01/01

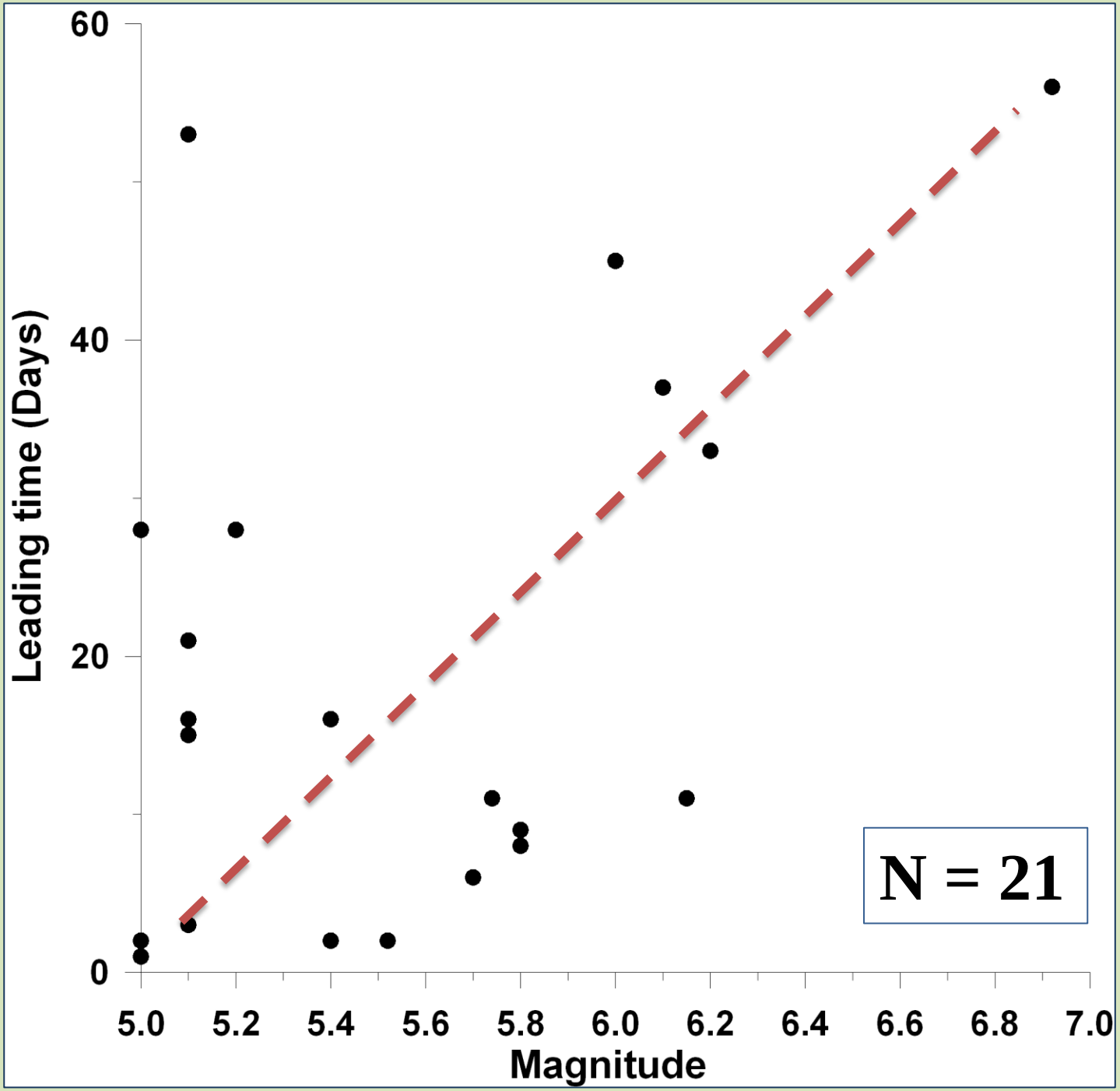

(a) frequency > 5.787×10^-7 Hz (20 days^-1)
x 10^-3
5
0
-5
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501
(b) = raw data - (a)
0
-0.05
-0.1
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501
(c) Residual + IMF points at frequency < 7.716×10^-8 Hz (150 days^-1)
0
-0.05
-0.1
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501
(d) 5.787×10^-7 Hz < frequncy < 7.716×10^-8 Hz
Displacement (m)
0
-0.05
-0.1
1 101 201 301 401 501 601 701 801 901 1001 1101 1201 1301 1401 1501
Day from 2006/01/01

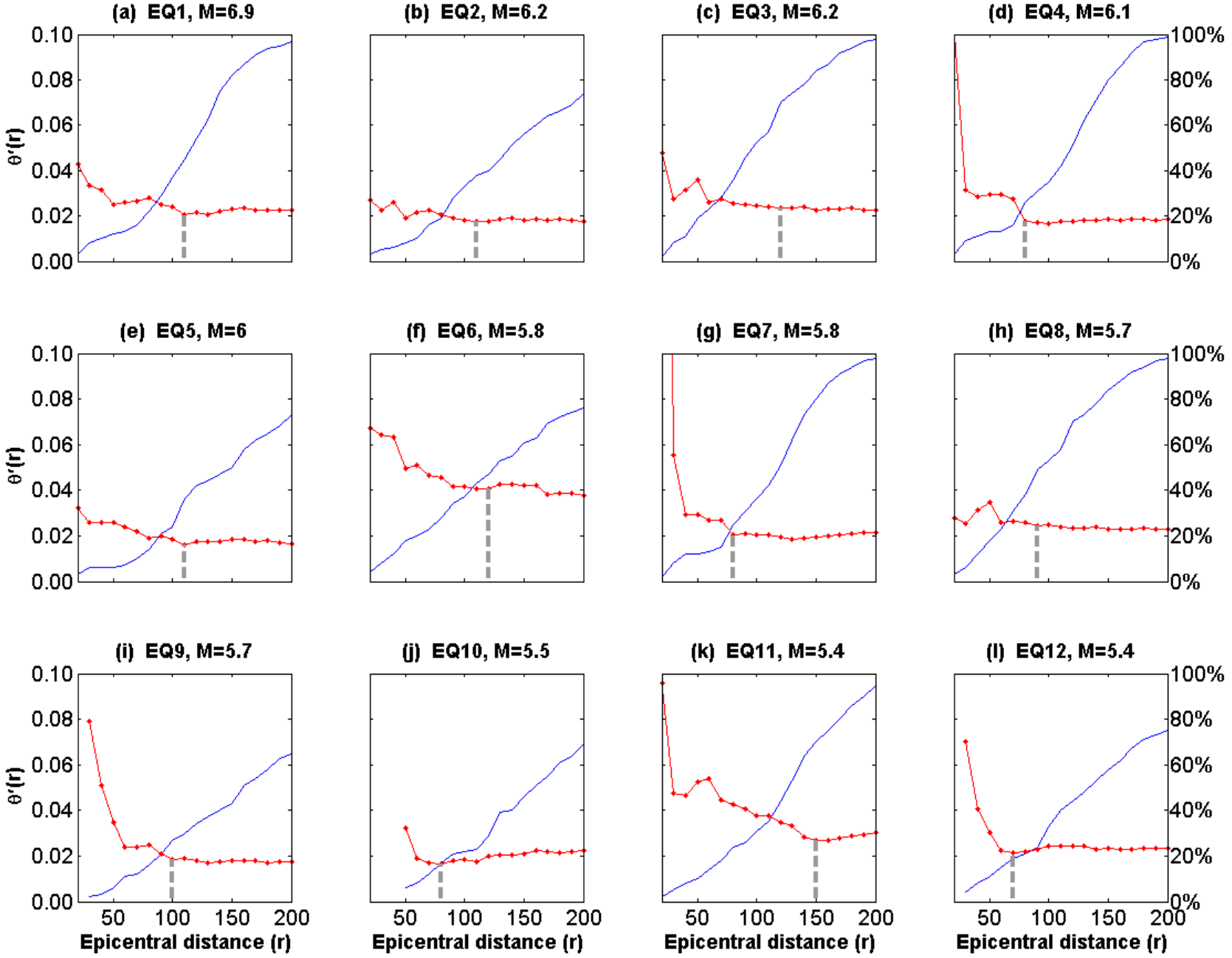

(a)
Mean
0.0141
Mean+2σ
0.0211
Proportions
30
20
10
0
4.26%
0.01
0.02
0.03
0.04
0.05
0.06
θ'
(b)
0.035
0.03
0.025
0.02
0.015
0.01
θ'
Leading time
-56 days
EQ
0.0211
-60
-40
-20
0
Day to the EQ32


N
W
E
S
25.0
24.5
24.0
23.5
23.0
22.5
22.0
Latitude
120.5
121.0
121.5
Longitude
7
11
20
18
17
1
6
4
21
8
12
13
14
2
5
19
16
9
15

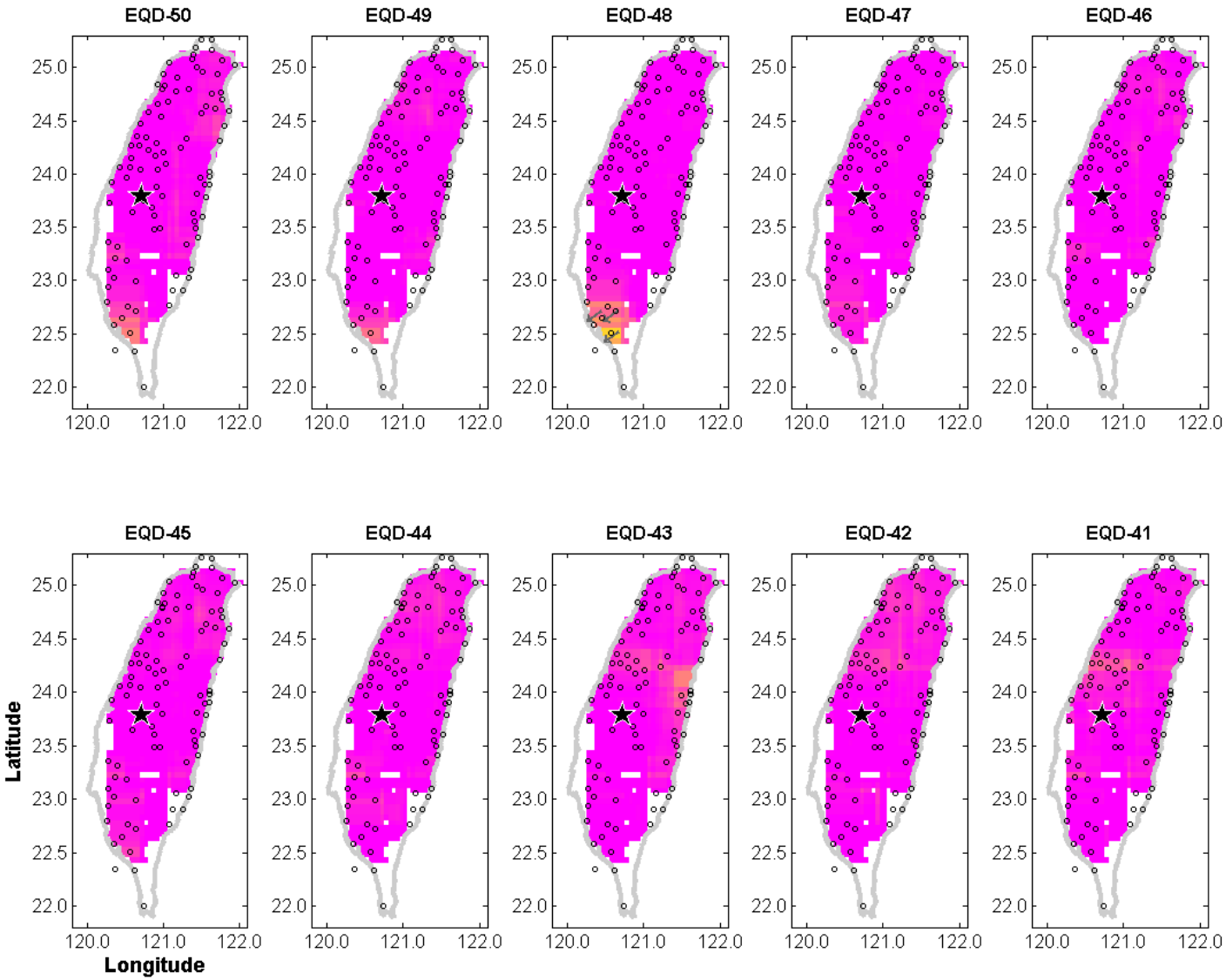
21/32 = 66%


N = 21
0.05
0.04
0.03
0.02
0.011
θ'
Mean + 2σ = 0.0211
Mean = 0.0141
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
Magnitude

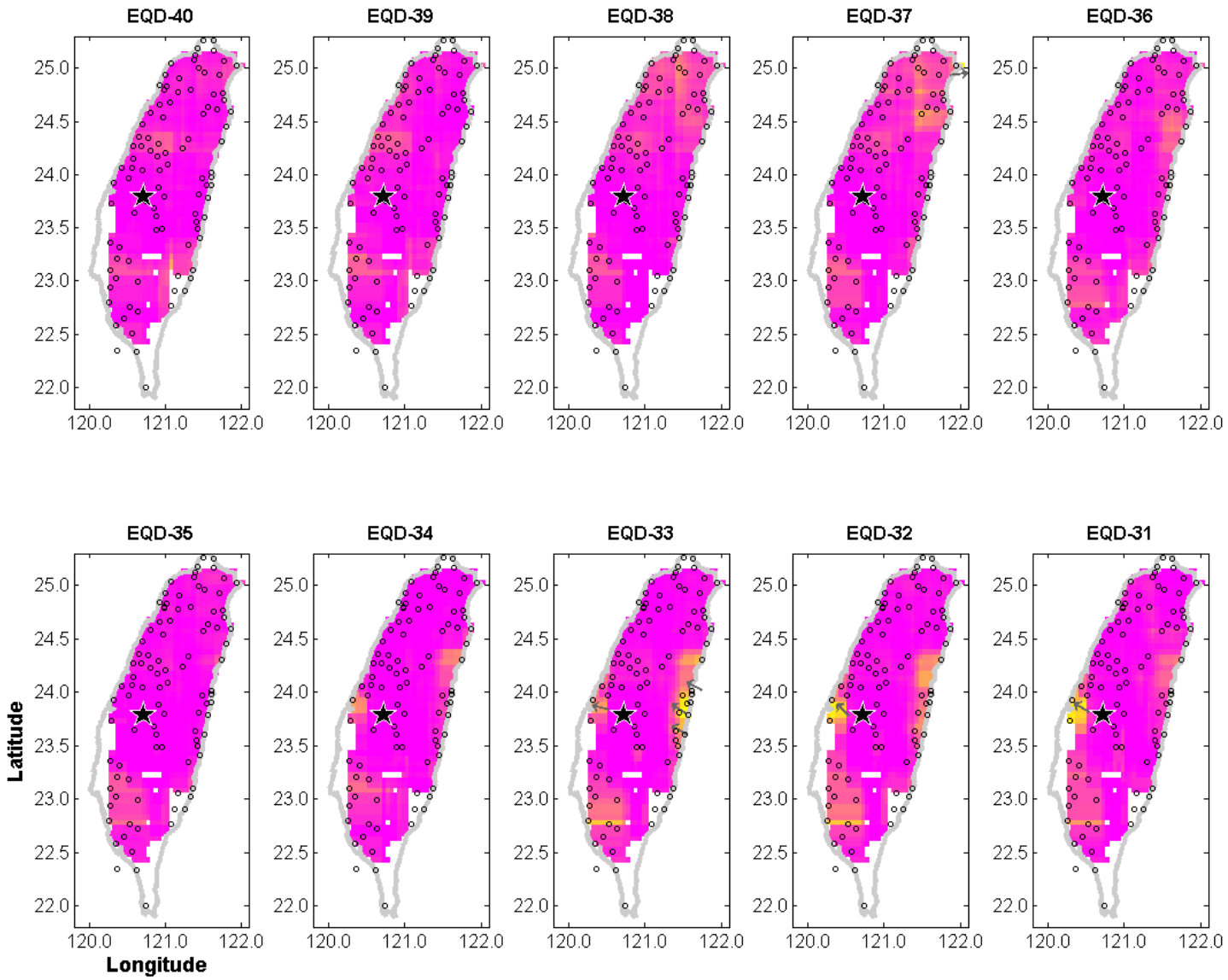

60
40
20
0
Leading time (Days)
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
Magnitude
N = 21


(a) EQ1, M=6.9
(b) EQ2, M=6.2
(c) EQ3, M=6.2
(d) EQ4, M=6.1
(e) EQ5, M=6
(f) EQ6, M=5.8
(g) EQ7, M=5.8
(h) EQ8, M=5.7
(i) EQ9, M=5.7
(j) EQ10, M=5.5
(k) EQ11, M=5.4
(l) EQ12, M=5.4
θ'(r)
0.10
0.08
0.06
0.04
0.02
0.00
100%
80%
60%
40%
20%
0%
50
100
150
200
Epicentral distance (r)

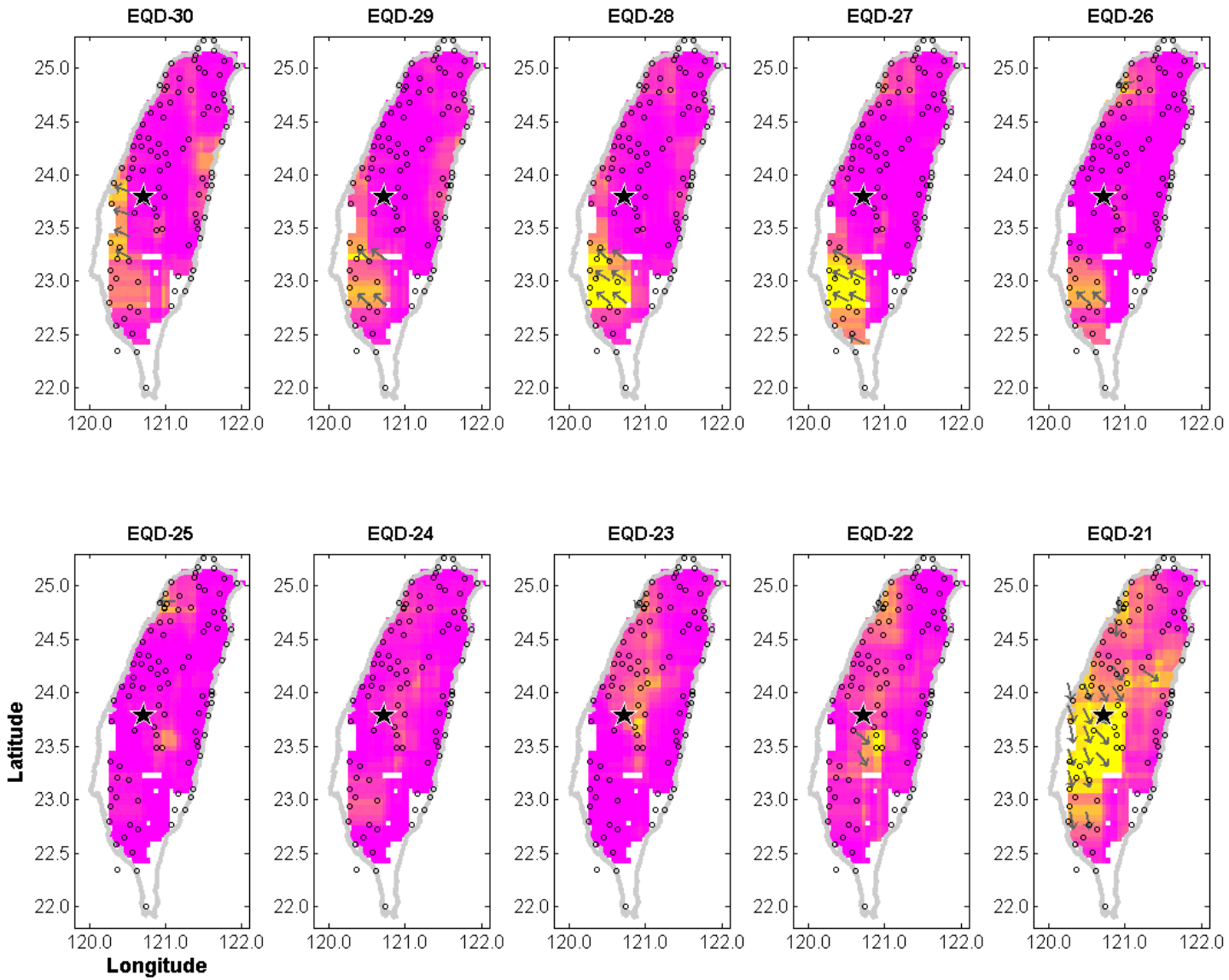
2009名間地震前50-41天 (M=6.2)



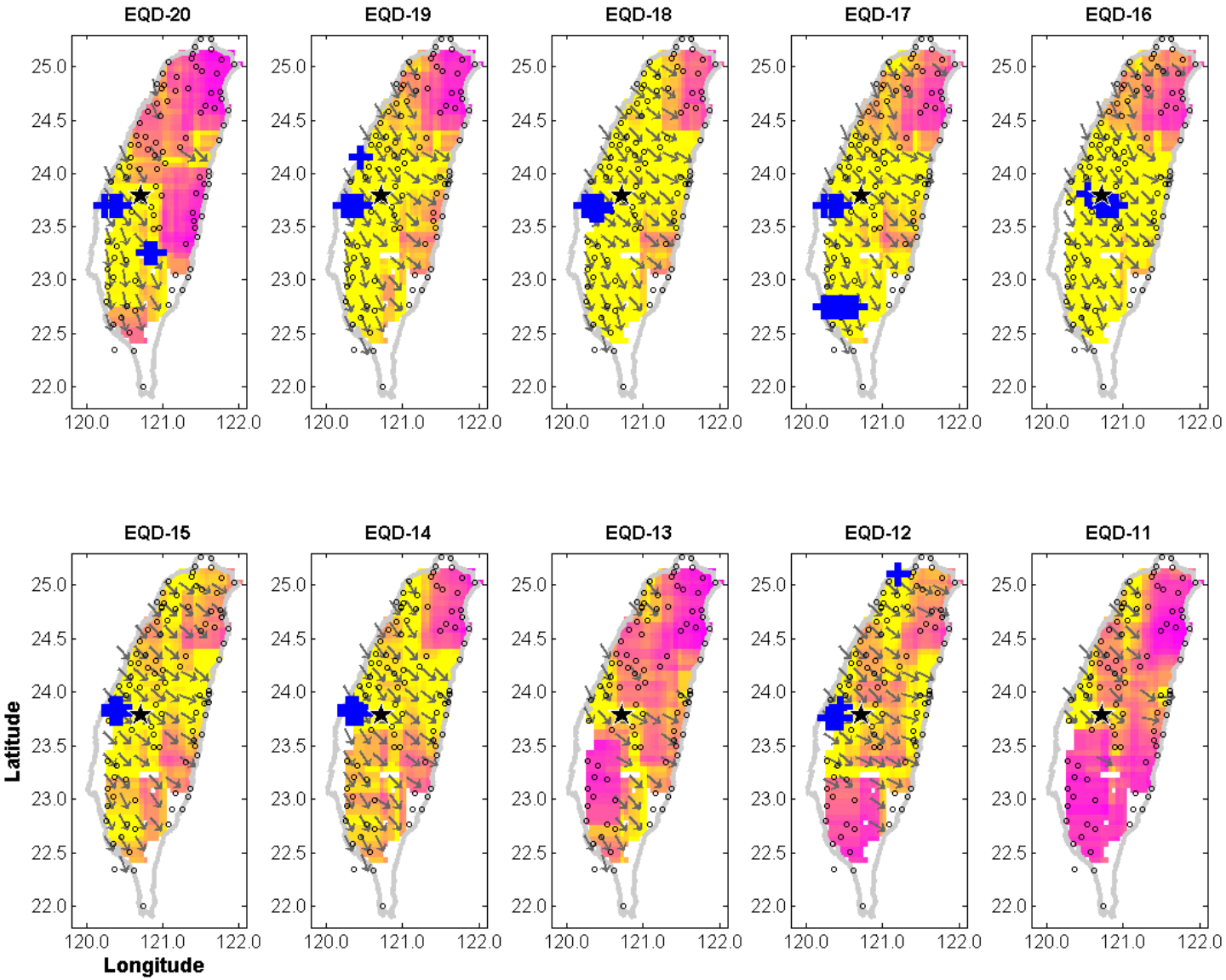
2009名間地震前40-31天



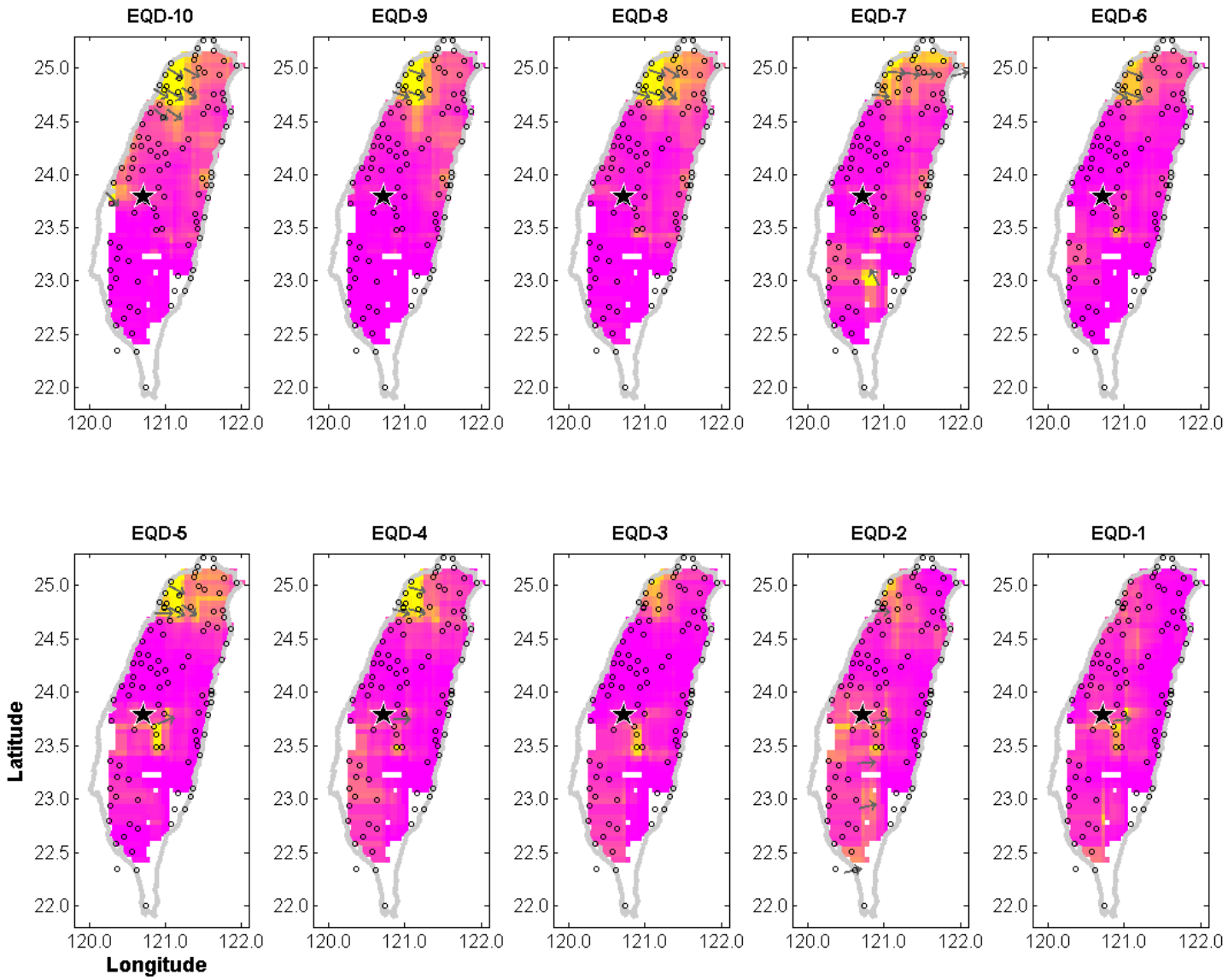
2009名間地震前30-21天



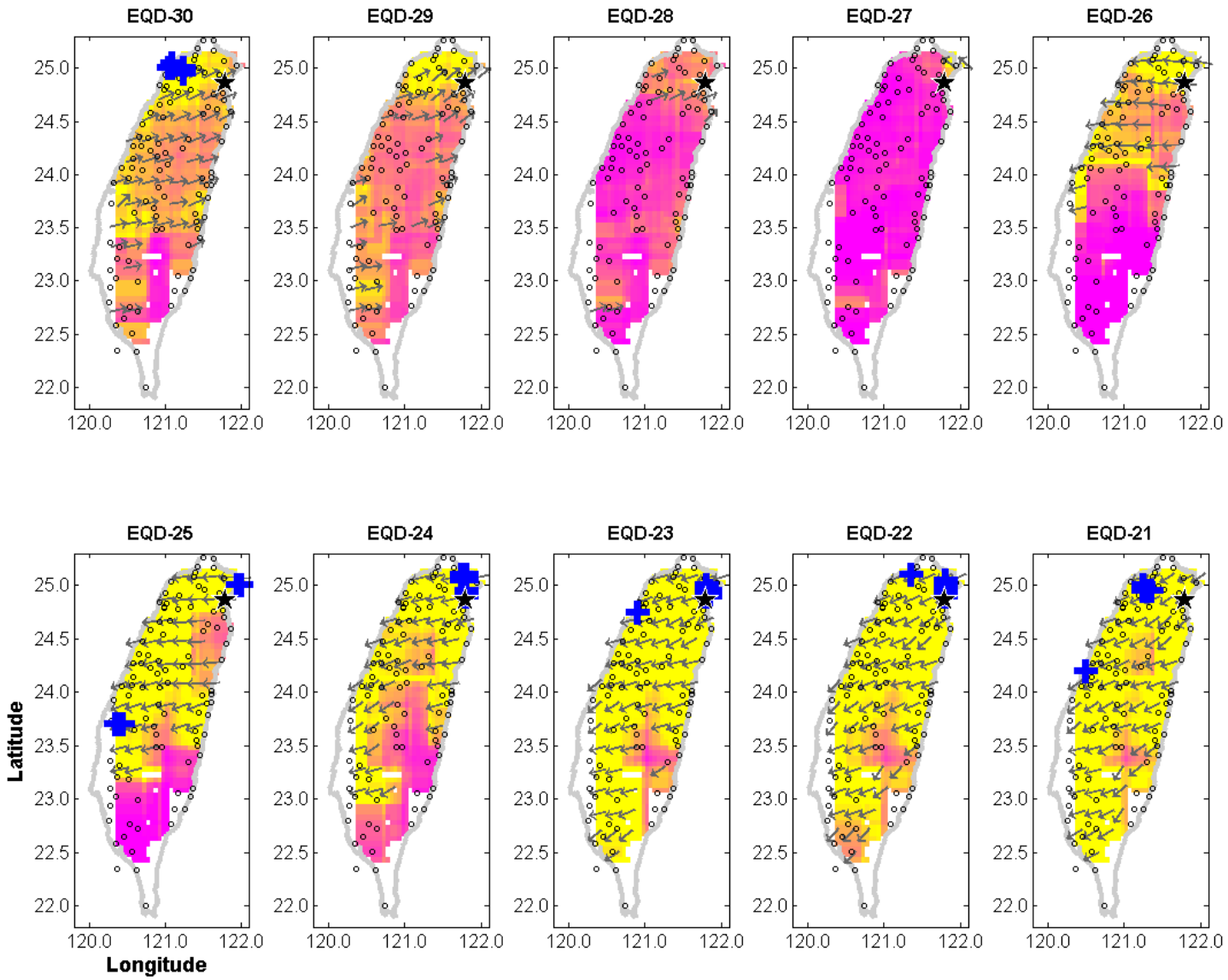
2009名間地震前20-11天



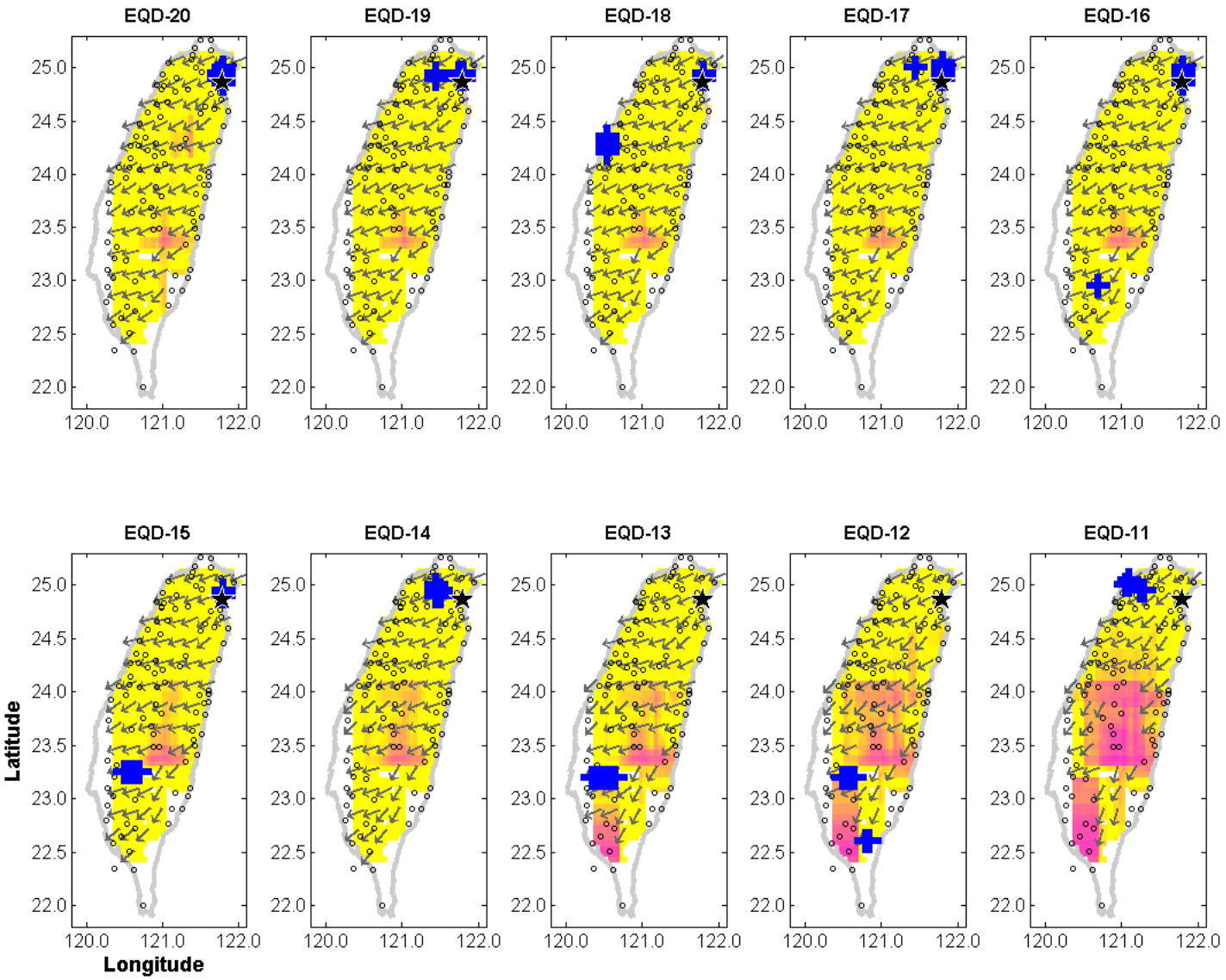
2009名間地震前10-1天



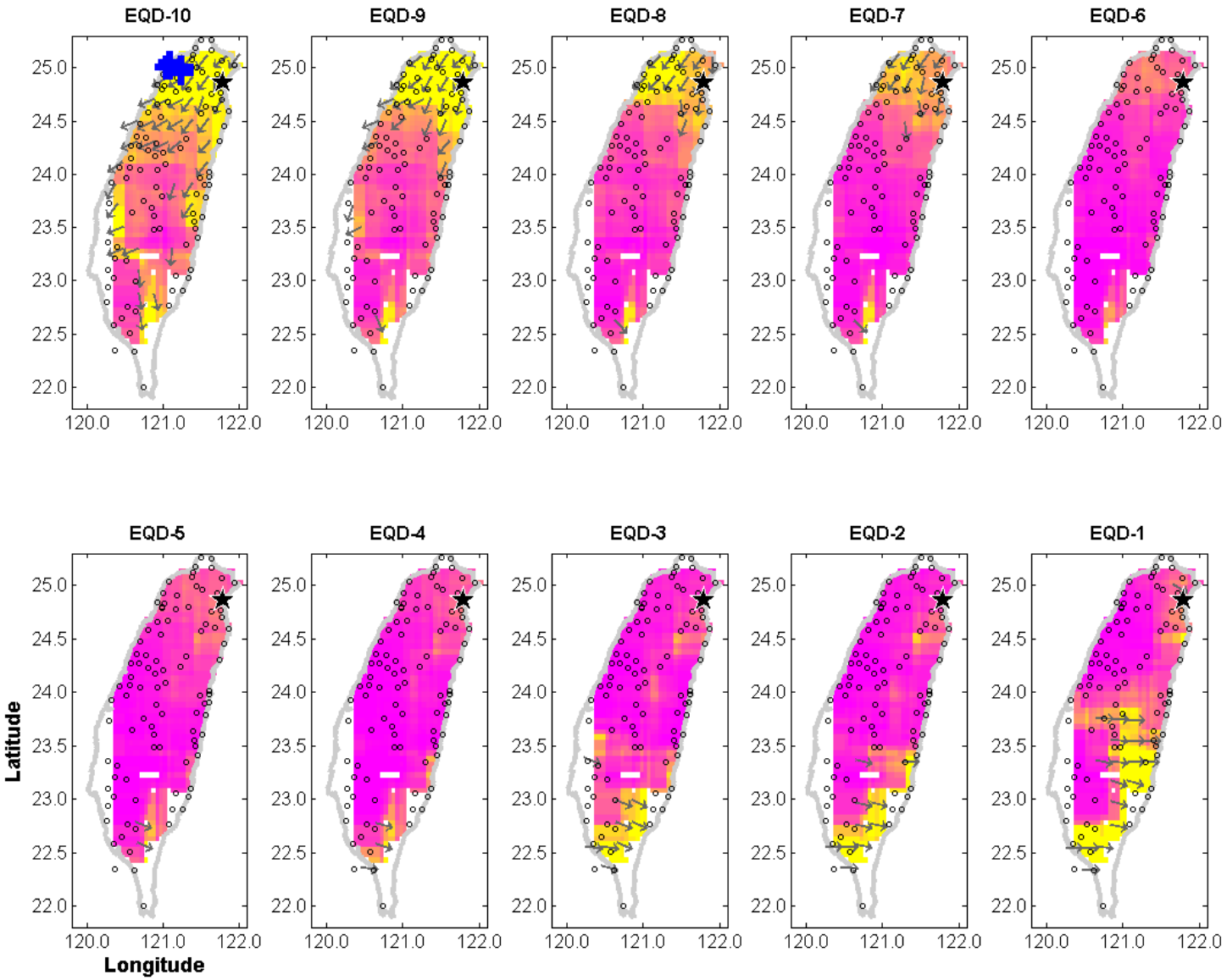
2008.6.1 M=5.8 前30-21天



2008.6.1 M=5.8 前20-11天



2008.6.1 M=5.8 前10-1天



- 台灣獨特的地質背景及密佈的觀測系統(GPS、地震儀、地下水位、地磁)提供一個絕佳的機會，讓我們深入了解地震發生前、後的地表及地下變形歷程，以及孕震的機制。
- 透過多重前兆指標(GPS、地震儀、地下水位、地磁)的交叉驗證，台灣有機會在未來幾年內，建立地震預警系統，對知災、防災、避災、救災都會有重要的助益。

ID	Year	Month	Day	Hour	Minute	Sec.	Mag.	Lon.	Lat.	θ'	LT
1	2006	4	1	10	2	19.54	6.2	121.081	22.884	0.0249	33
2	2006	4	15	22	40	55.37	6.0	121.304	22.856	0.0303	45
3	2006	4	28	9	5	26.96	5.2	121.611	23.985	NaN	NaN
4	2006	6	4	9	6	1.05	5.0	121.263	22.854	NaN	NaN
5	2007	7	16	23	42	52.18	5.0	121.545	23.570	0.0316	2
6	2007	7	23	13	40	2.44	5.8	121.636	23.716	0.0280	9
7	2007	8	9	0	55	47.36	5.7	121.085	22.650	0.0273	6
8	2007	10	11	3	5	1.70	5.2	121.850	24.749	NaN	NaN
9	2007	10	17	14	40	0.03	5.4	121.612	23.501	NaN	NaN
10	2007	11	28	21	5	13.72	5.4	121.976	24.781	0.0320	16
11	2007	12	5	1	41	42.53	5.1	121.187	23.075	0.0259	21
12	2008	2	17	20	33	2.32	5.4	121.461	23.307	0.0483	2
13	2008	3	4	17	31	47.48	5.2	120.696	23.207	0.0288	28
14	2008	4	14	15	39	44.45	5.1	121.333	22.834	NaN	NaN
15	2008	5	13	18	27	55.34	5.0	121.041	22.766	0.0238	1
16	2008	6	1	16	59	23.74	5.8	121.790	24.861	0.0308	8
17	2008	8	1	18	55	49.32	5.1	121.526	24.048	0.0294	15
18	2008	12	2	3	16	54.23	5.7	121.486	23.338	NaN	NaN
19	2008	12	23	0	4	43.82	5.3	120.551	22.946	NaN	NaN
20	2009	1	3	22	4	34.97	5.1	121.733	24.154	0.0376	16
21	2009	4	17	12	37	48.89	5.3	121.682	23.917	NaN	NaN
22	2009	6	28	9	34	56.19	5.3	121.753	24.182	NaN	NaN
23	2009	7	26	1	0	12.37	5.4	120.957	23.685	NaN	NaN
24	2009	7	26	6	10	59.79	5.4	121.318	23.429	NaN	NaN
25	2009	8	21	20	57	44.74	5.1	120.464	22.364	0.0267	53
26	2009	10	3	17	36	6.28	6.1	121.579	23.648	0.0262	37
27	2009	10	22	23	5	5.13	5.1	121.488	22.685	0.0270	3
28	2009	11	5	9	32	57.66	6.2	120.719	23.789	0.0315	11
29	2009	11	5	11	34	21.26	5.7	120.755	23.769	0.0318	11
30	2009	11	15	14	47	49.14	5.5	122.174	24.946	0.0293	2
31	2009	11	21	17	27	51.26	5.0	121.762	24.222	0.0248	28
32	2009	12	19	13	2	16.34	6.9	121.663	23.788	0.0263	56

ID	Year	Month	Day	Hour	Minte	Second	Lon.	Lat.	Magnitude
1	2009	12	19	13	2	16.34	121.663	23.788	6.9
2	2006	4	1	10	2	19.54	121.081	22.884	6.2
3	2009	11	5	9	32	57.66	120.719	23.789	6.2
4	2009	10	3	17	36	6.28	121.579	23.648	6.1
5	2006	4	15	22	40	55.37	121.304	22.856	6.0
6	2007	7	23	13	40	2.44	121.636	23.716	5.8
7	2008	6	1	16	59	23.74	121.790	24.861	5.8
8	2009	11	5	11	34	21.26	120.755	23.769	5.7
9	2007	8	9	0	55	47.36	121.085	22.650	5.7
10	2009	11	15	14	47	49.14	122.174	24.946	5.5
11	2007	11	28	21	5	13.72	121.976	24.781	5.4
12	2008	2	17	20	33	2.32	121.461	23.307	5.4