行政院農業委員會
水土保持局

近即時震波式同震山崩潛感圖(2)



Seal et al. 2020 USGS
ver. 2.0, Feb 2022
Year: 1772-2021

楊哲銘、趙韋安

國立聯合大學

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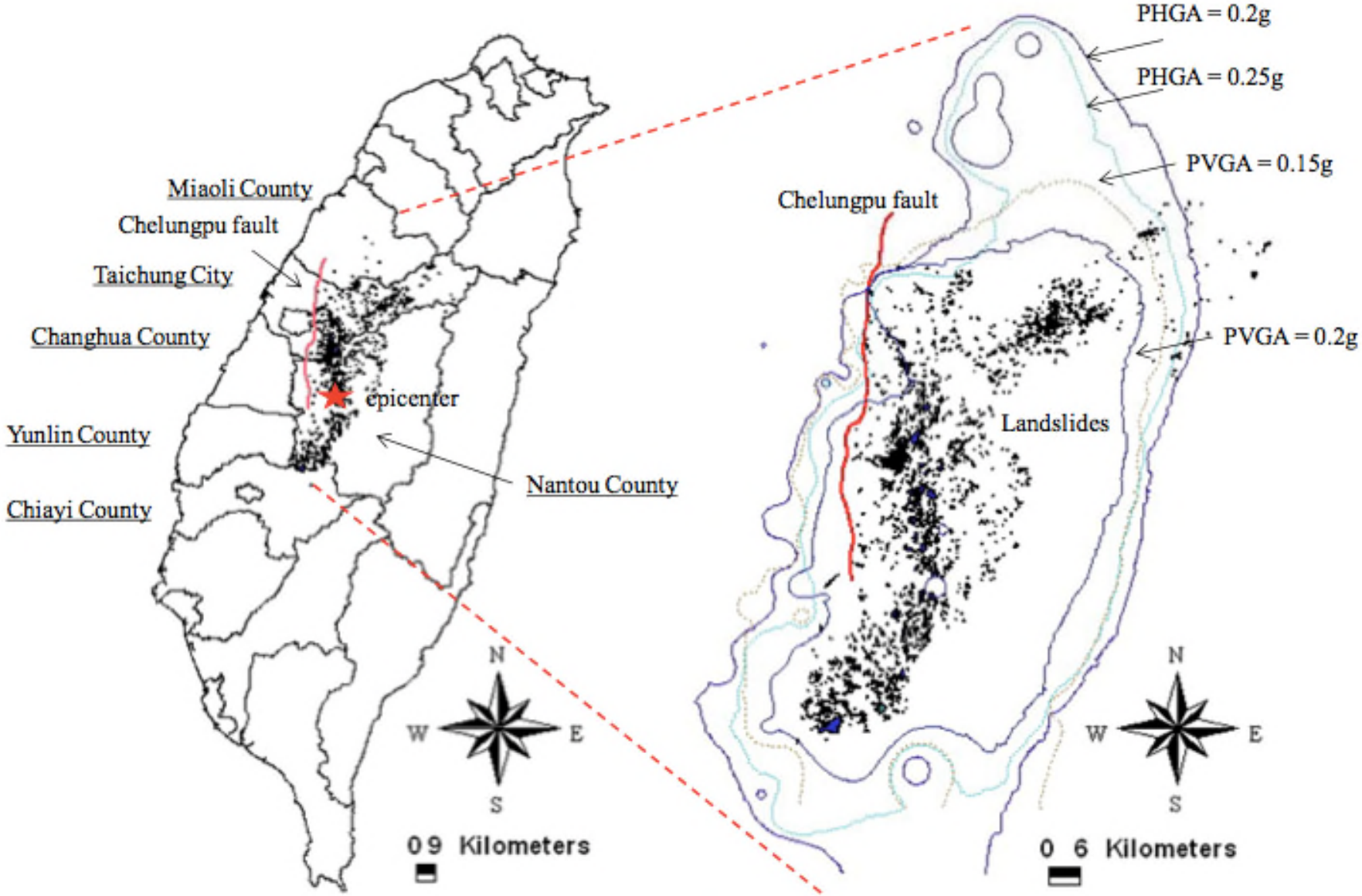
工程地質與地質災害研究室
Engineering Geology & Geohazard Lab

地表過程地動監測研究室
Comprehensive Landtoring Lab

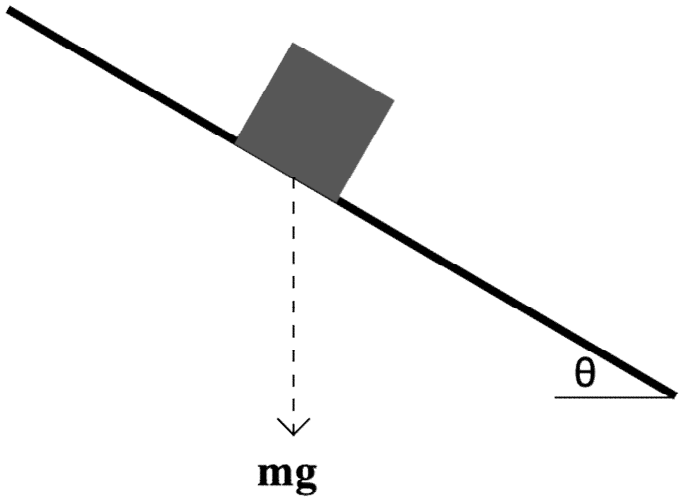
Earthquake + Landslide = Coseismic Landslide

1994 Nanao
1995 Nioudou
1998 Rueyli
1999 Chichi
2000 Nantou
2009 Mingjian
2009 Hualien
2010 Jiasian
2013/3 Nantou
2013/6 Nantou
2016 Meinong
2019 Hualien
2022/3 Hualien
2022/9 Guangshan
2022/9 Chishang

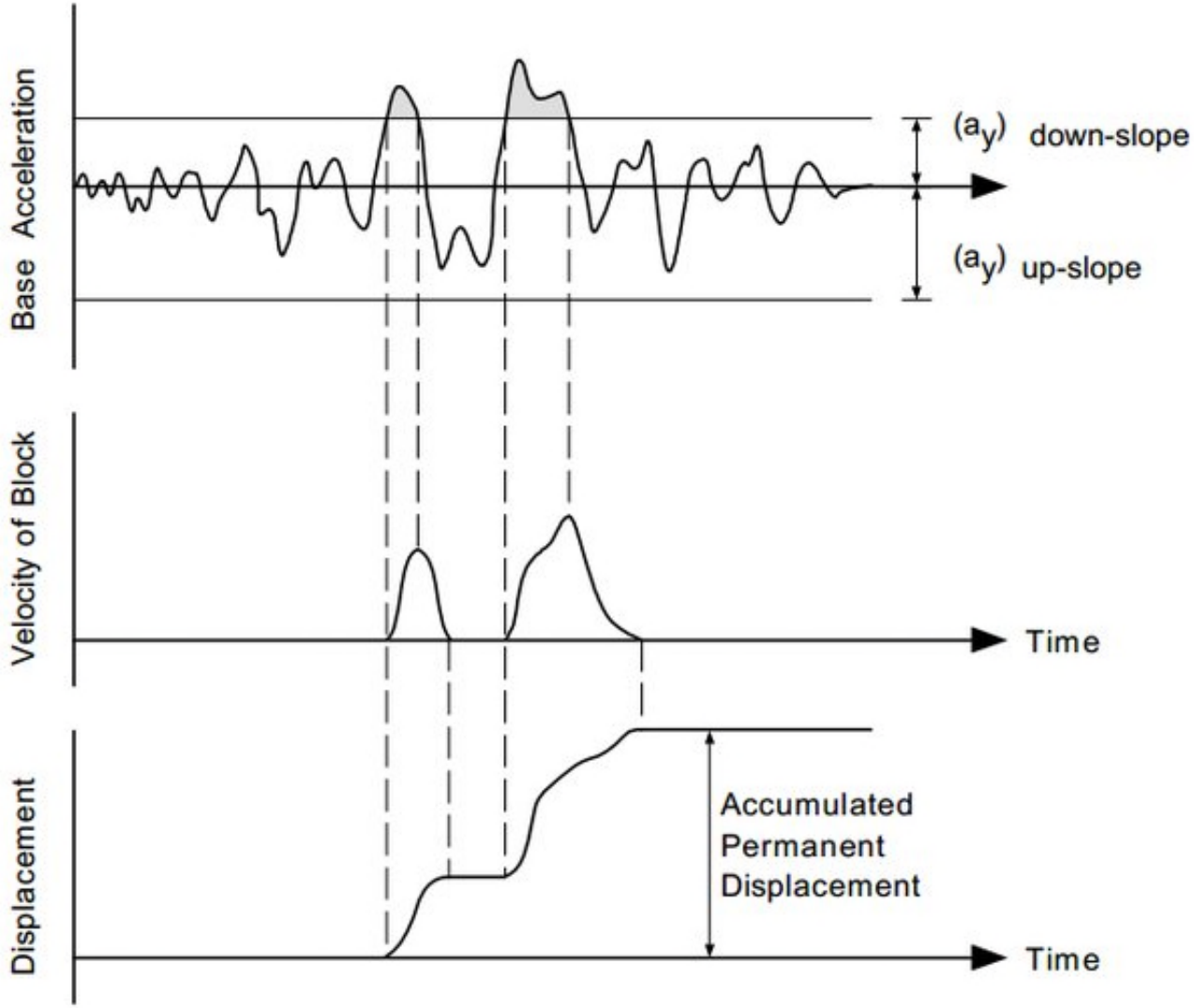


Chen et al. (2012)

Newmark Analysis



$$A_c = (FS - 1)\, g \sin\theta$$



(Newmark, 1965; Jibson, 1993; Jibson et al., 1998; Goldgruber, 2015)

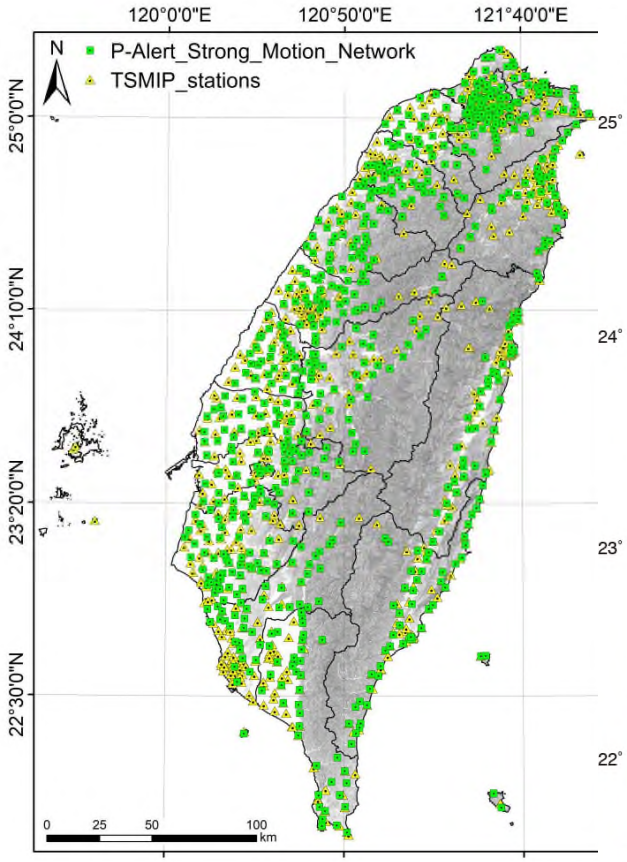
Target Slope (TS) : 175
Represented Station (RS): 116

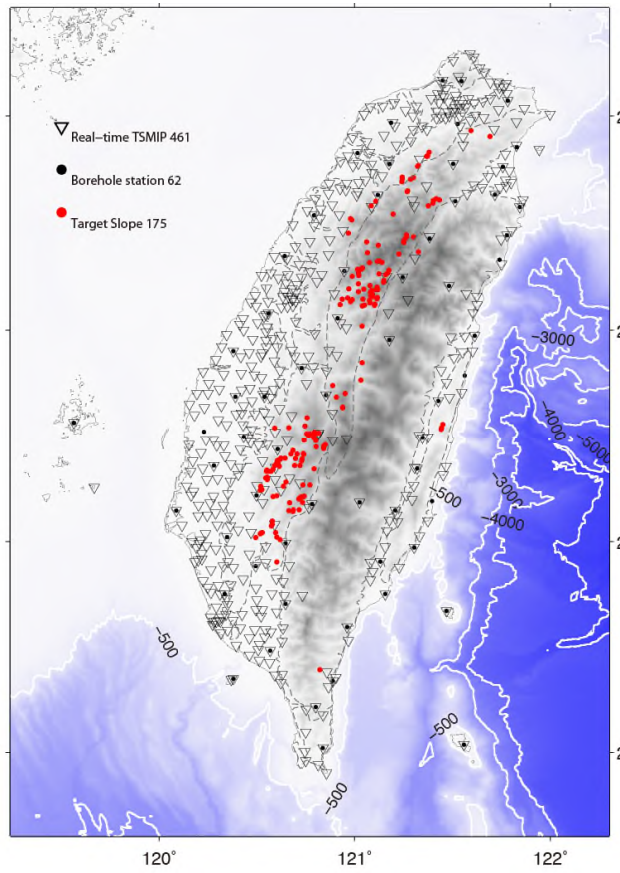
TSMIP Stations

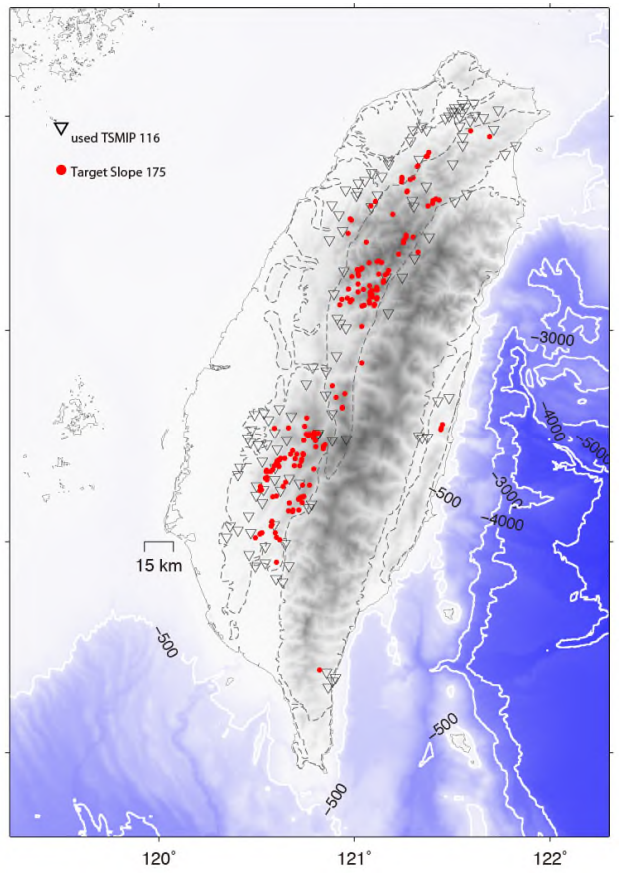
TS Red circle

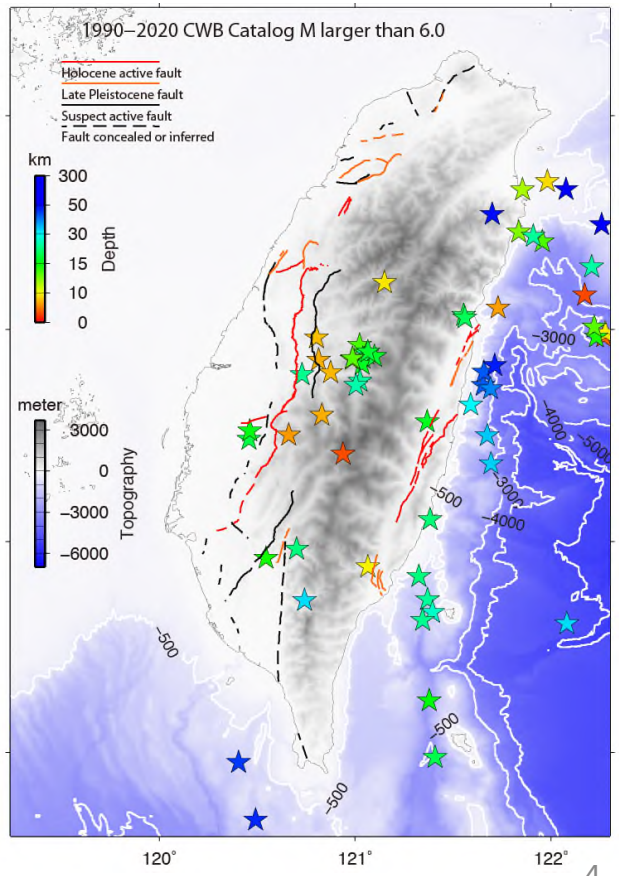
dis < 15 km RS Invert triangle

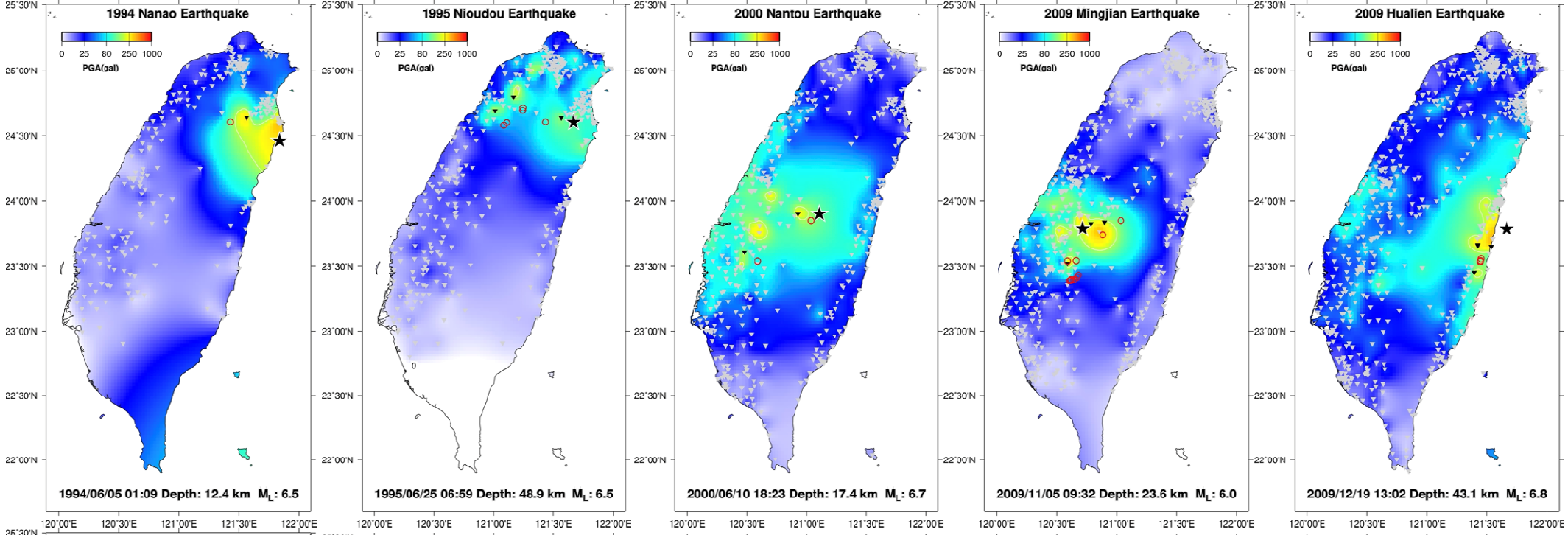
1990-2020 Historical EQ M > 6.0



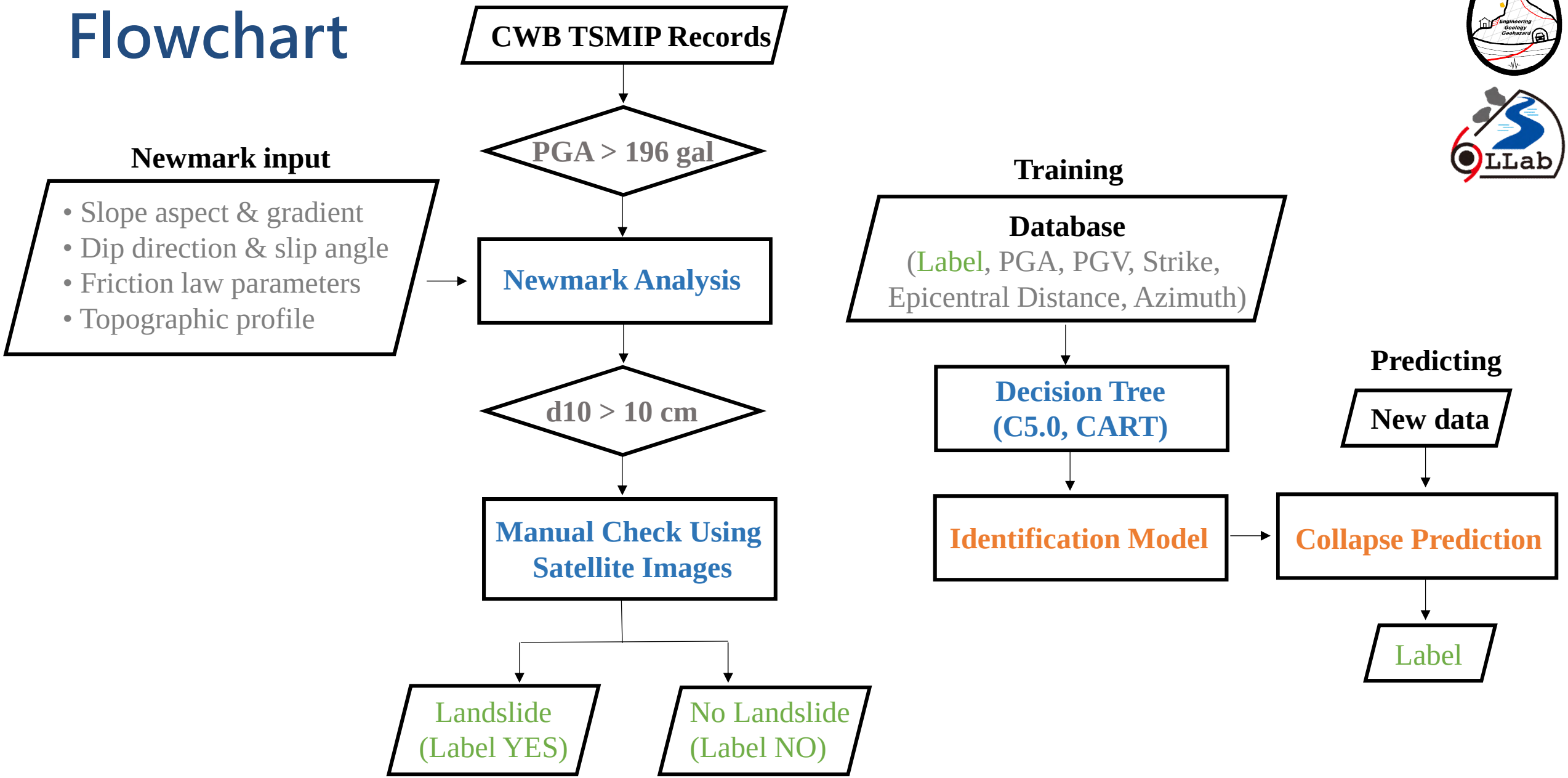






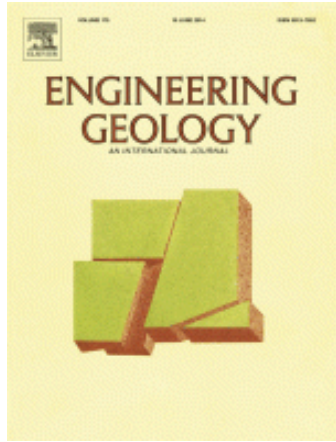

1994 Nanao Earthquake
1994/06/05 01:09 Depth: 12.4 km ML: 6.5
1995 Nioudou Earthquake
1995/06/25 06:59 Depth: 48.9 km ML: 6.5
2000 Nantou Earthquake
2000/06/10 18:23 Depth: 17.4 km ML: 6.7
2009 Mingjian Earthquake
2009/11/05 09:32 Depth: 23.6 km ML: 6.0
2009 Hualien Earthquake
2009/12/19 13:02 Depth: 43.1 km ML: 6.8
2010 Jiasian Earthquake
2010/03/04 00:18 Depth: 22.4 km ML: 6.4
327 Nantou Earthquake
2013/03/27 02:03 Depth: 17.7 km ML: 6.2
602 Nantou Earthquake
2013/06/02 05:43 Depth: 13.2 km ML: 6.5
2016 Meinong Earthquake
2016/02/05 19:57 Depth: 14.6 km ML: 6.6
2022 Hualien Earthquake
2022/03/22 17:41 Depth: 30.6 km ML: 6.6
PGA(gal)
0 25 80 250 1000

Flowchart


CWB TSMIP Records
PGA > 196 gal
Newmark input
• Slope aspect & gradient
• Dip direction & slip angle
• Friction law parameters
• Topographic profile
Newmark Analysis
d10 > 10 cm
Manual Check Using Satellite Images
Landslide (Label YES)
No Landslide (Label NO)
Training
Database (Label, PGA, PGV, Strike, Epicentral Distance, Azimuth)
Decision Tree (C5.0, CART)
Identification Model
Predicting
New data
Collapse Prediction
Label

Physical phenomena: Sliding block model

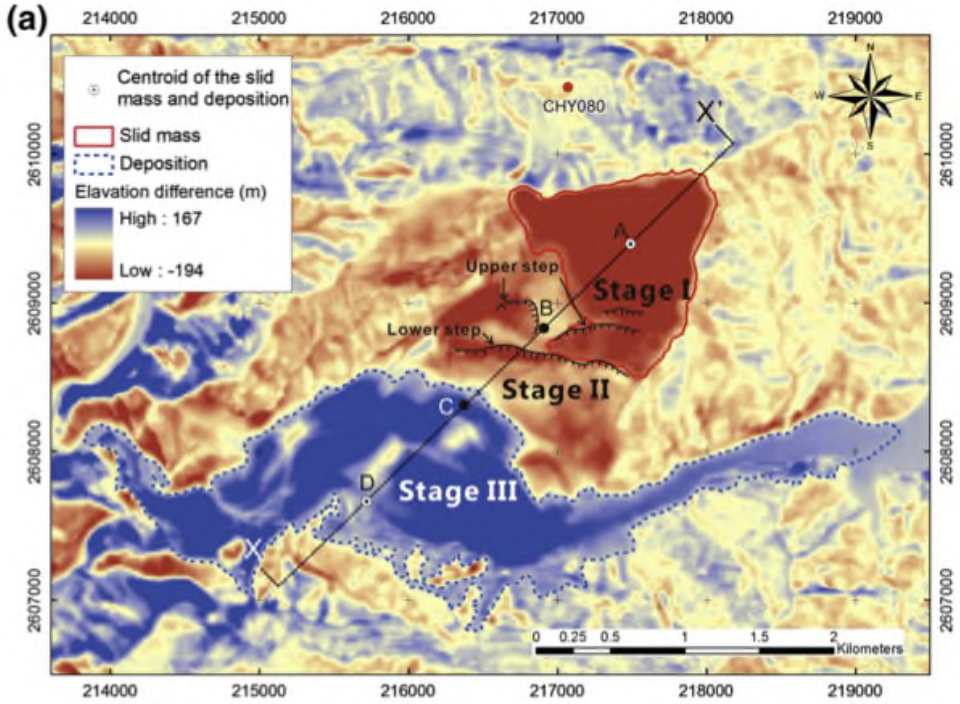
-Seismic records from TSMIP
-Lab. Experiment: frictional properties
-Slope geometry: slope angle & aspect

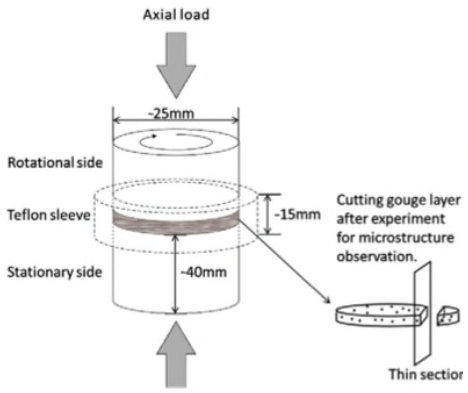


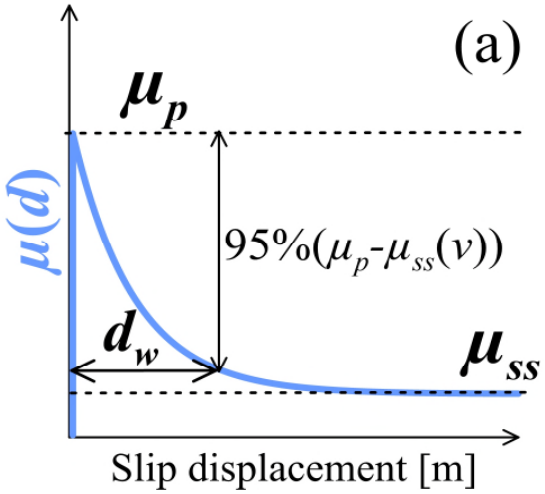
-Yang et al. 2014

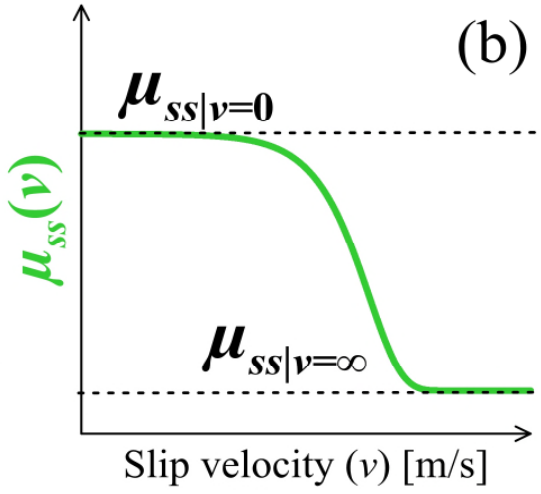
$$\mu(d) = \mu_{ss} + (\mu_p - \mu_{ss})\exp(\ln(0.05)d/d_w)$$

$$\mu_{ss}(v) = \mu_{ss|v=\infty} + (\mu_{ss|v=0} - \mu_{ss|v=\infty})\exp(-v^A/V_C)$$







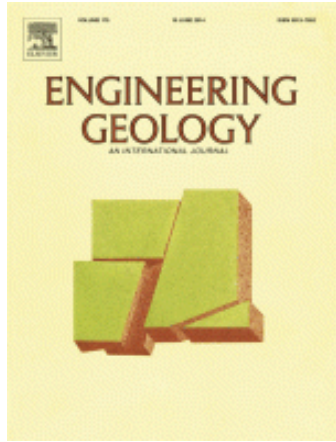


Physical phenomena: Sliding block model

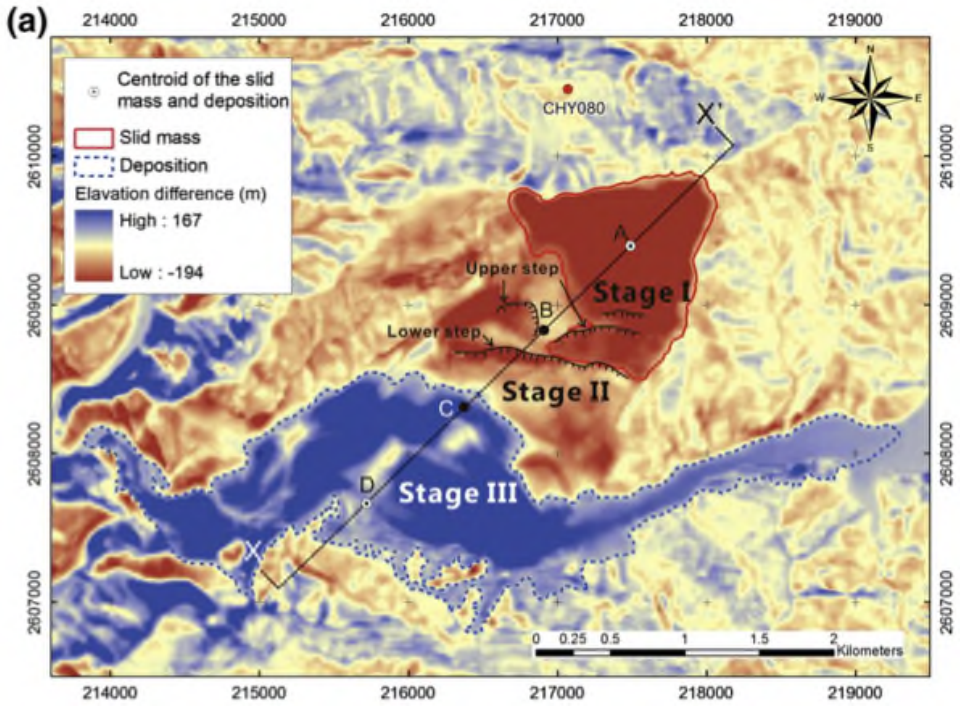
-Seismic records from TSMIP

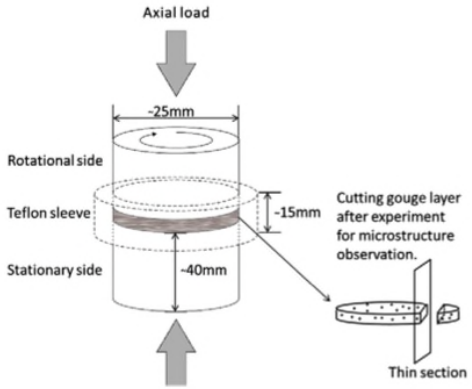
-Lab. Experiment: frictional properties

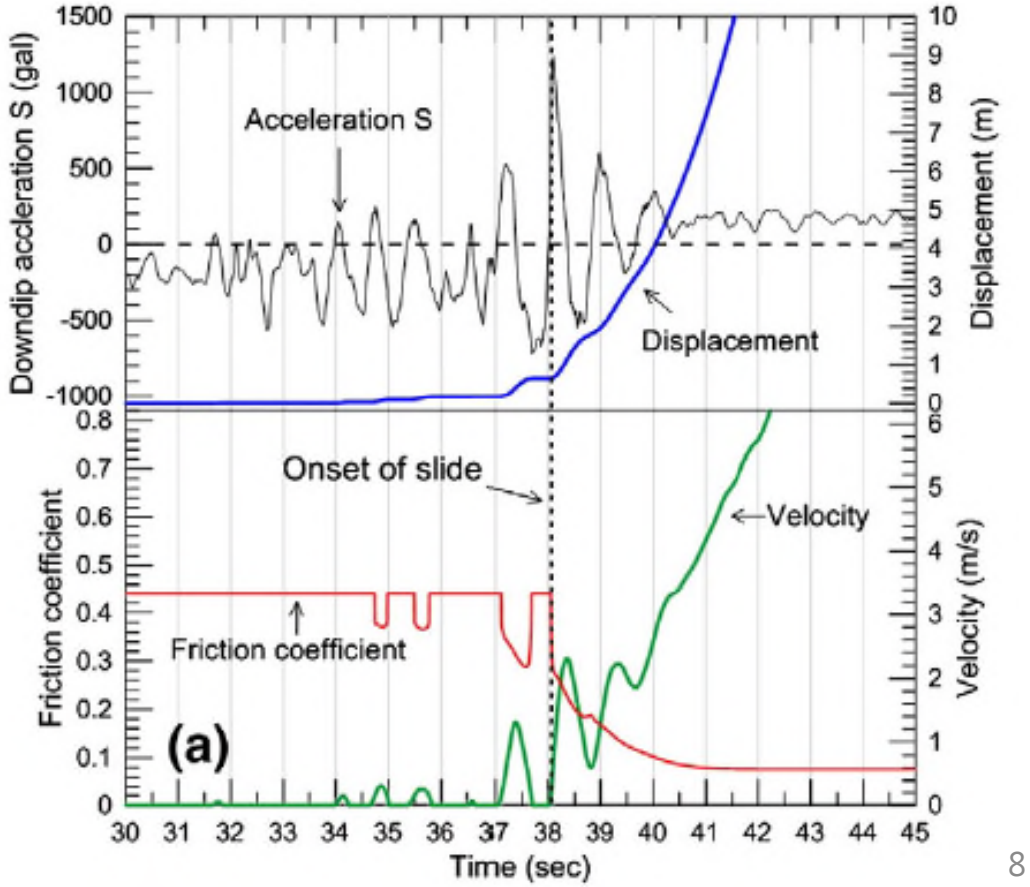
-Slope geometry: slope angle & aspect



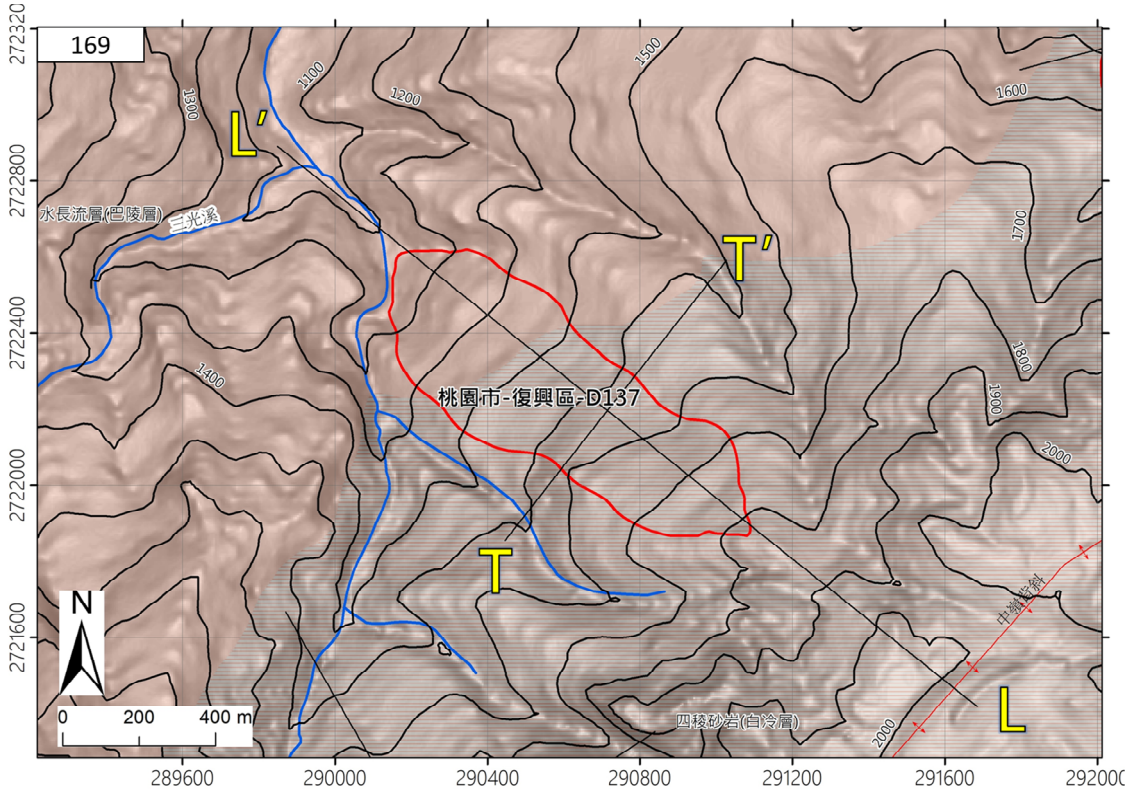
-Yang et al. 2014

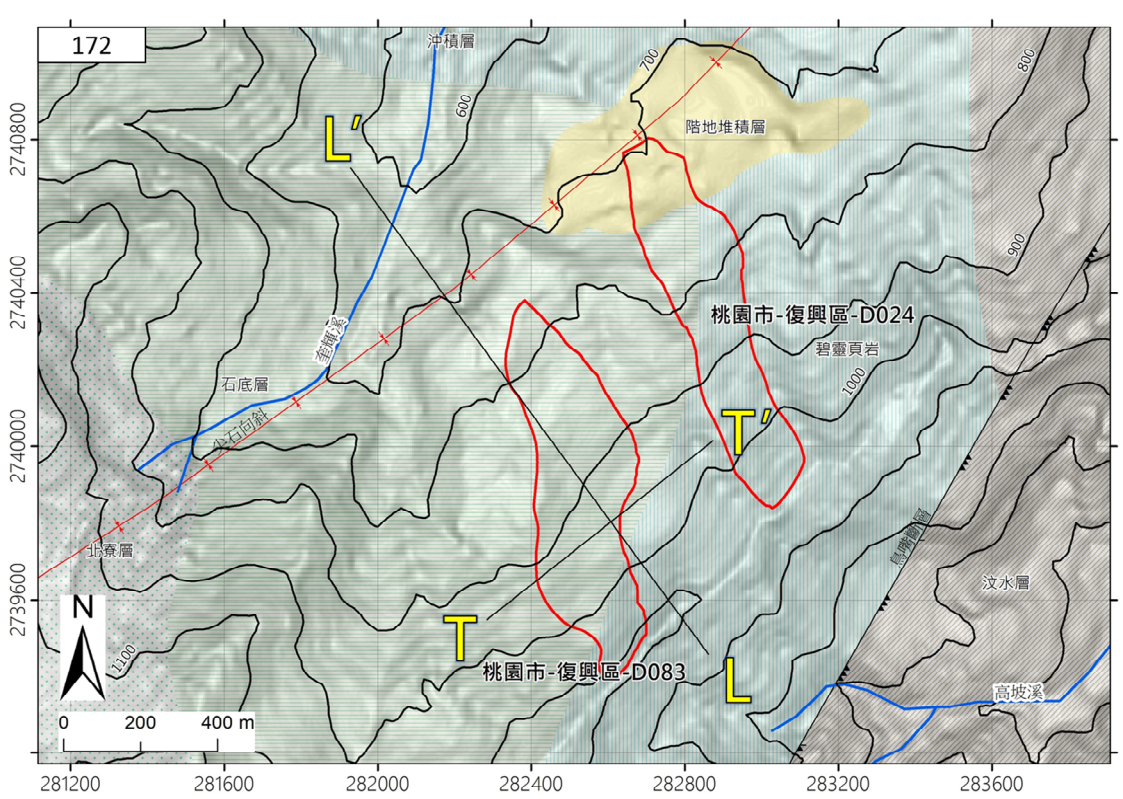


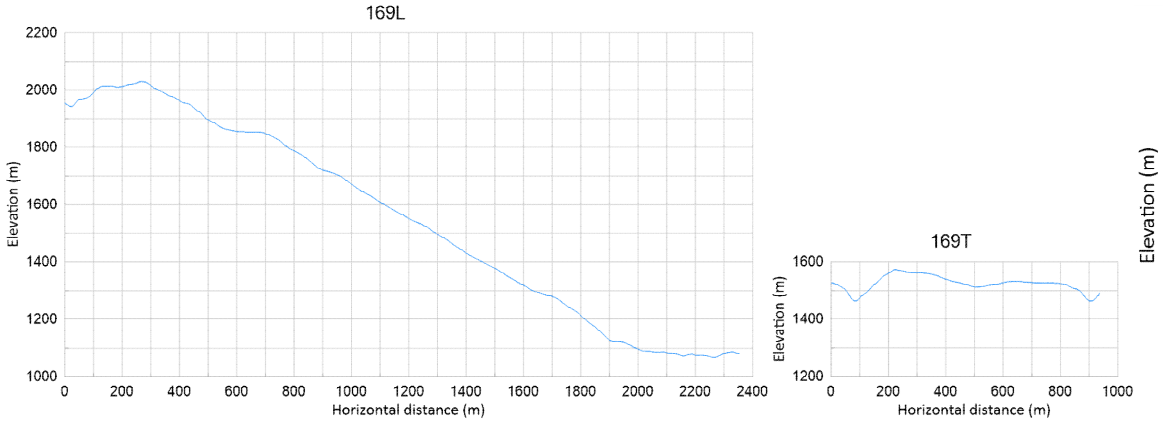




Potential Large-scale Planar Failures







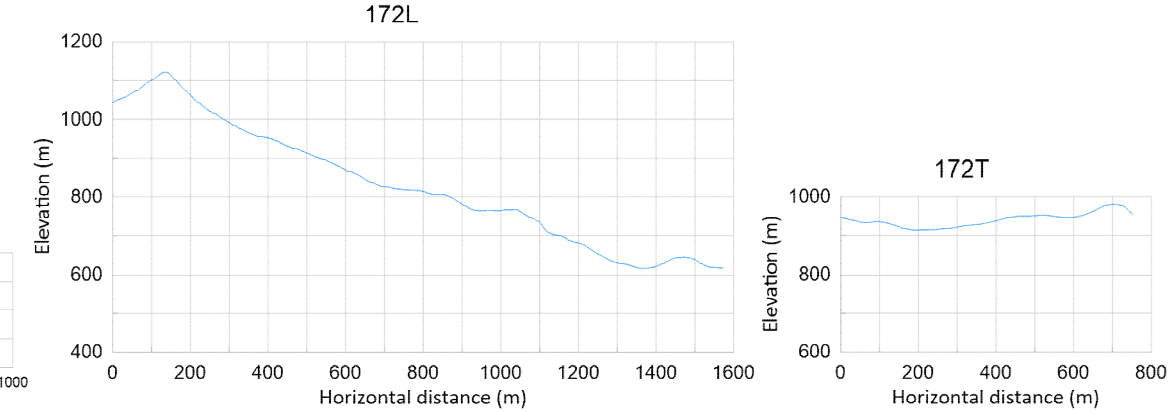
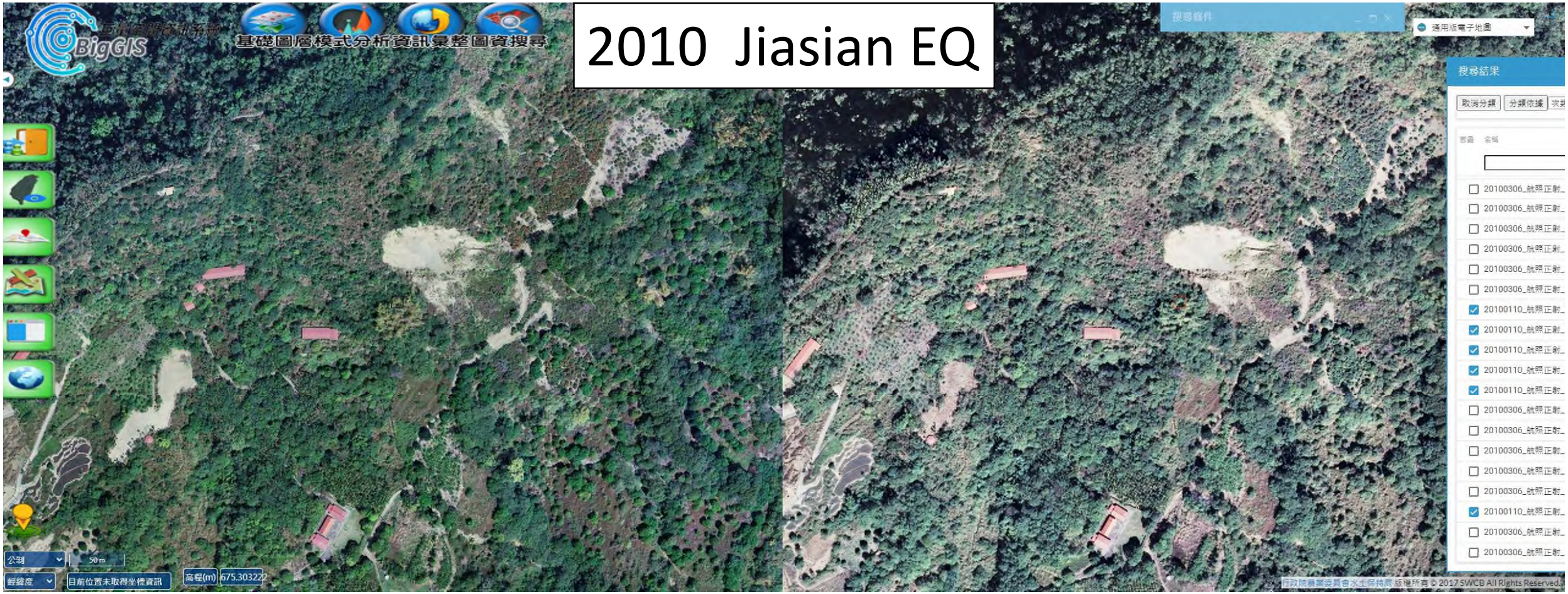


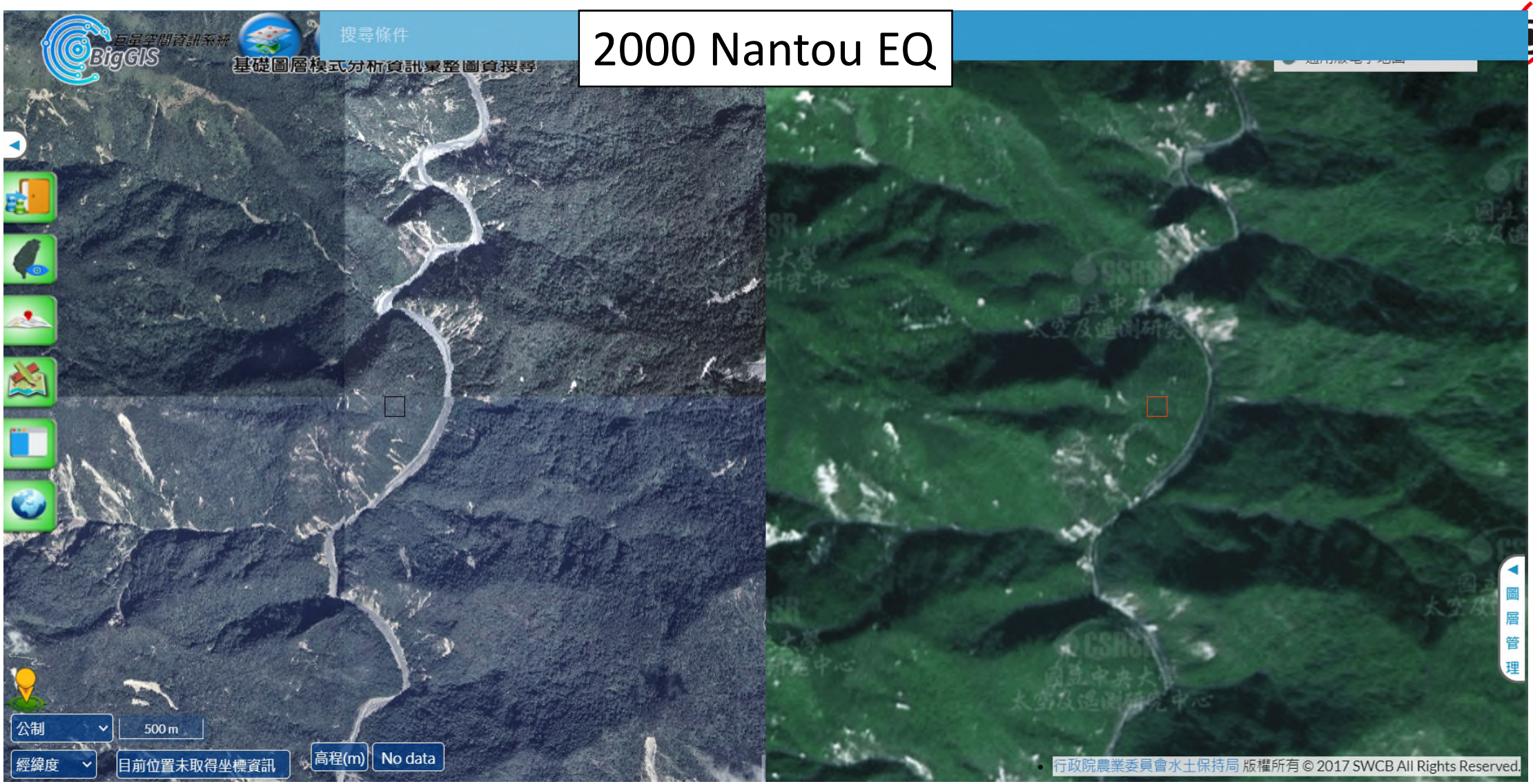
Image Interpretation (BigGIS)

Slope ID: 064 (2010/01/10) (2010/03/06)



Slope ID: 053

2001/10/17 1999 SPOT image



Case Study: 0206 Meinong EQ

未滿足
PGA > 196 gal or
d10 > 10 cm

滿足
PGA > 196 gal and
d10 > 10 cm

Predicted Label

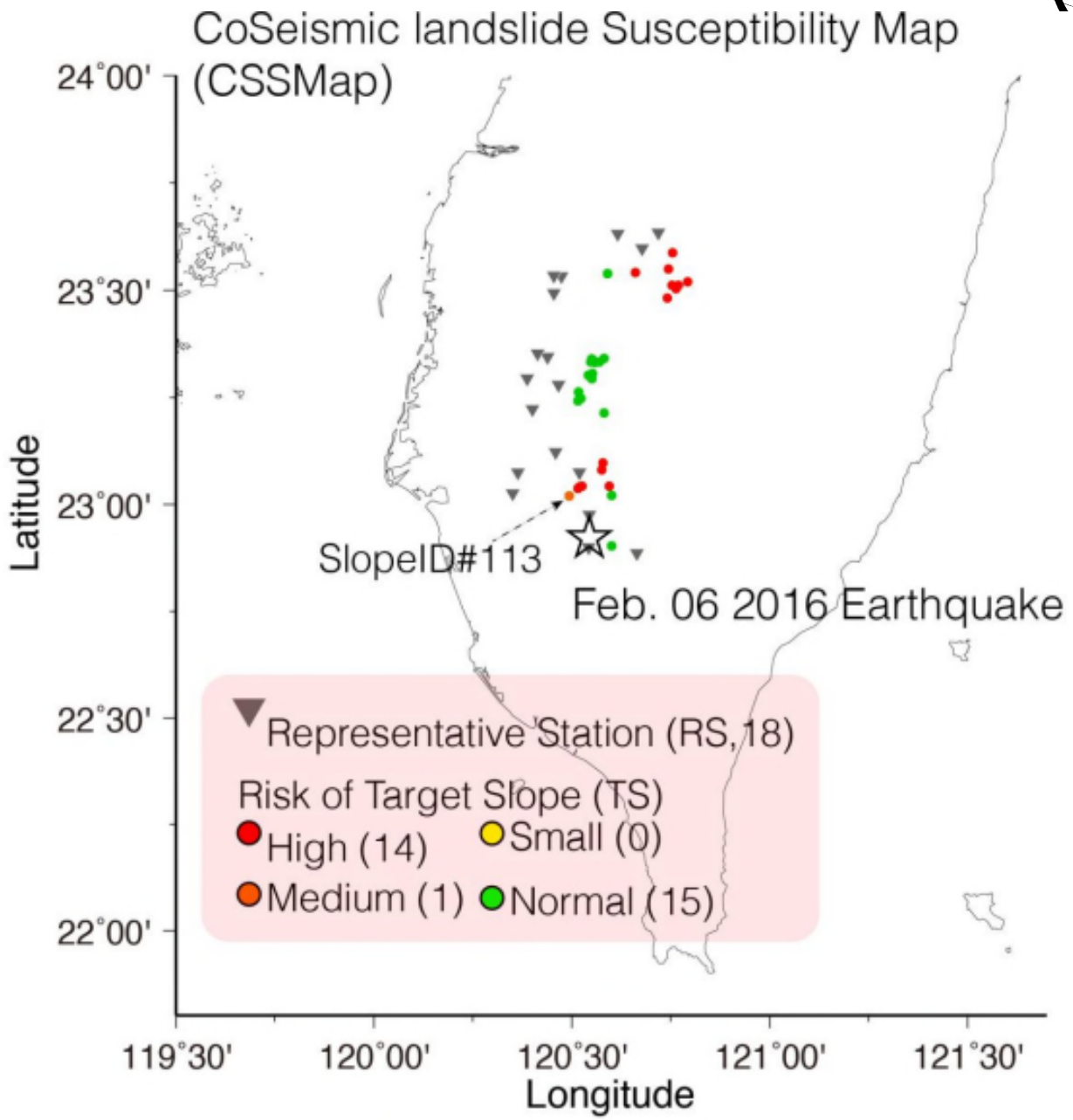
YES → **M**

NO → **N**

Susceptibility

High	Medium	Small	Normal

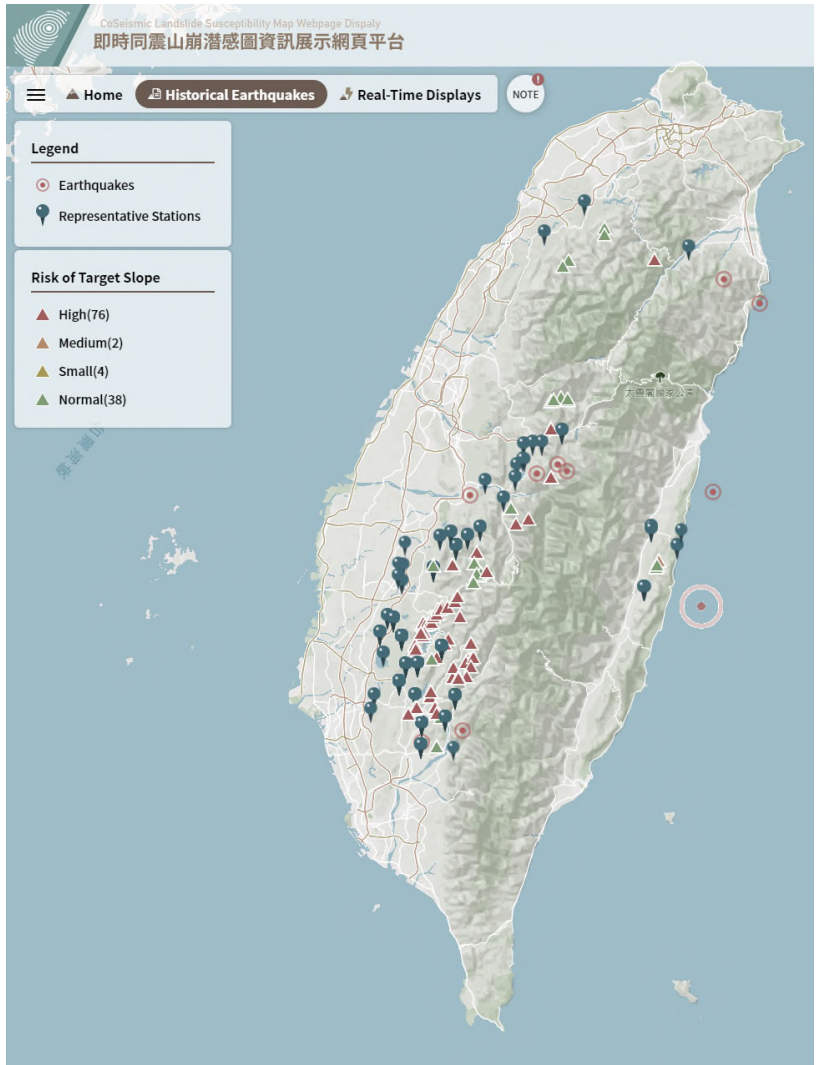
Proportional=M/(M+N)

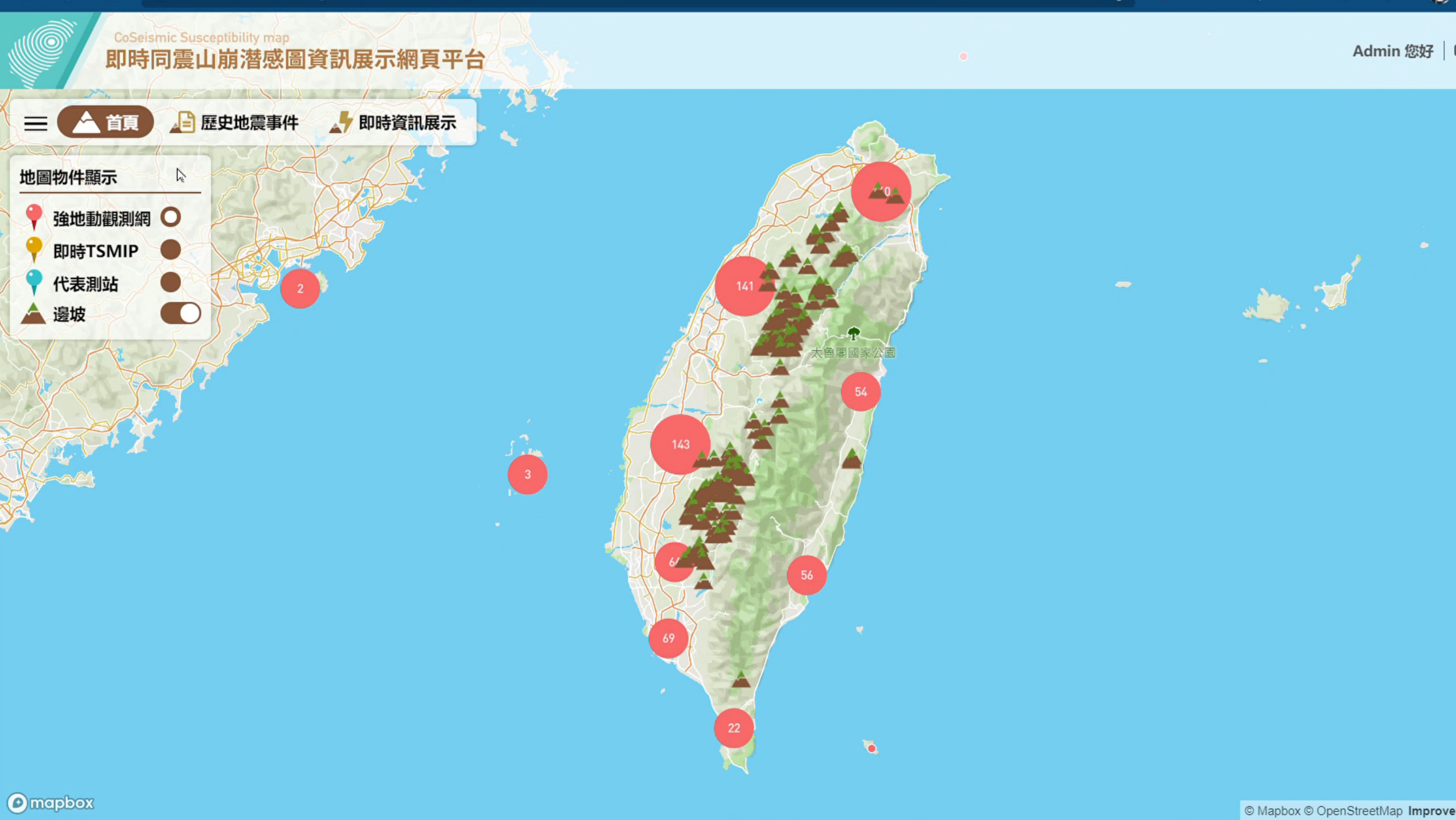


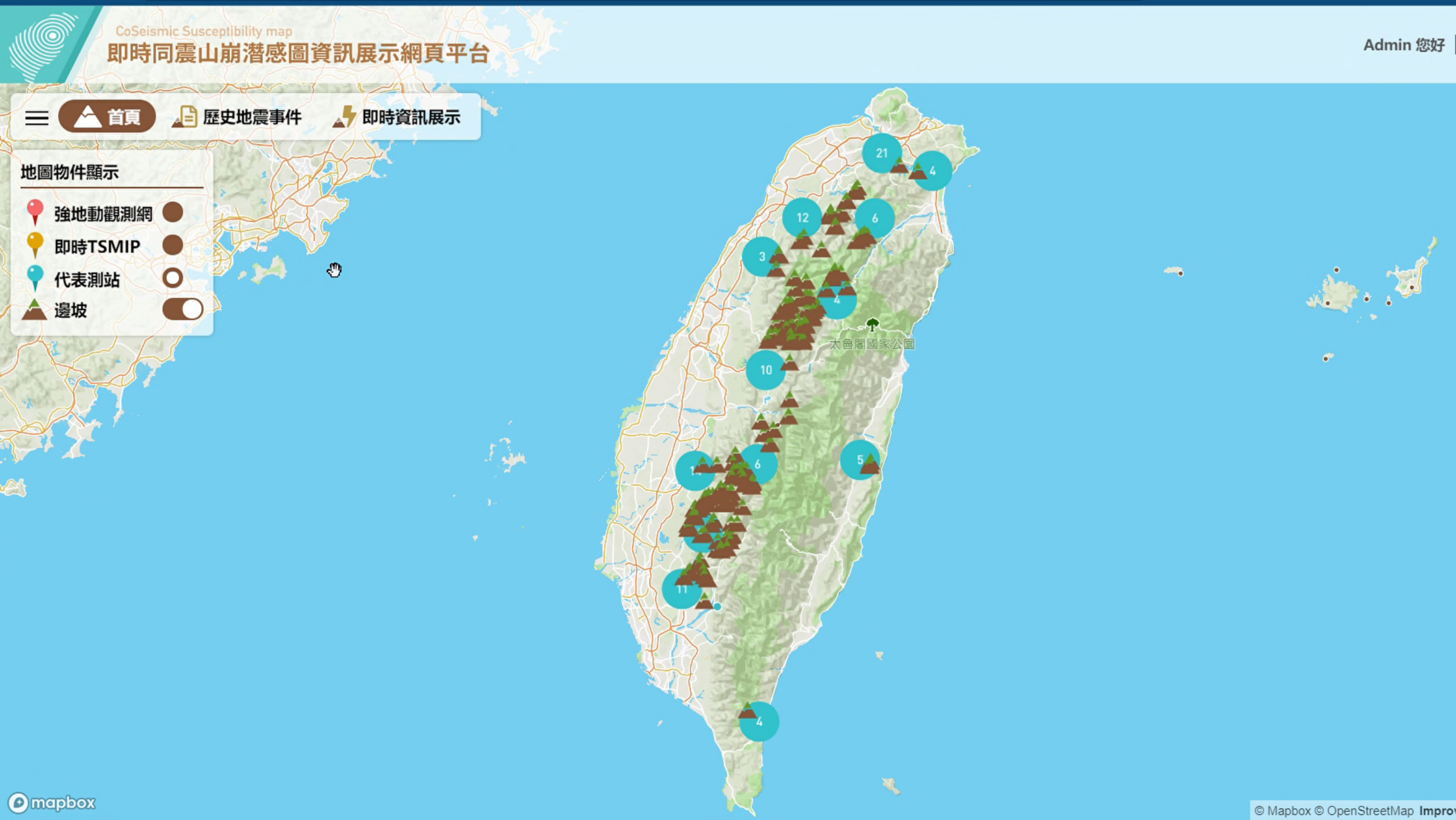
CoSeismic Susceptibility map-Webpage display platform

同震山崩潛感圖資訊展示平台

CSS-Web




CoSeismic Susceptibility map
即時同震山崩潛感圖資訊展示網頁平台
Admin 您好
首頁
歷史地震事件
即時資訊展示
地圖物件顯示
強地動觀測網
即時TSMIP
代表測站
邊坡
2
3
141
54
143
56
69
22
太魯閣國家公園
mapbox
© Mapbox © OpenStreetMap Improve


CoSeismic Susceptibility map
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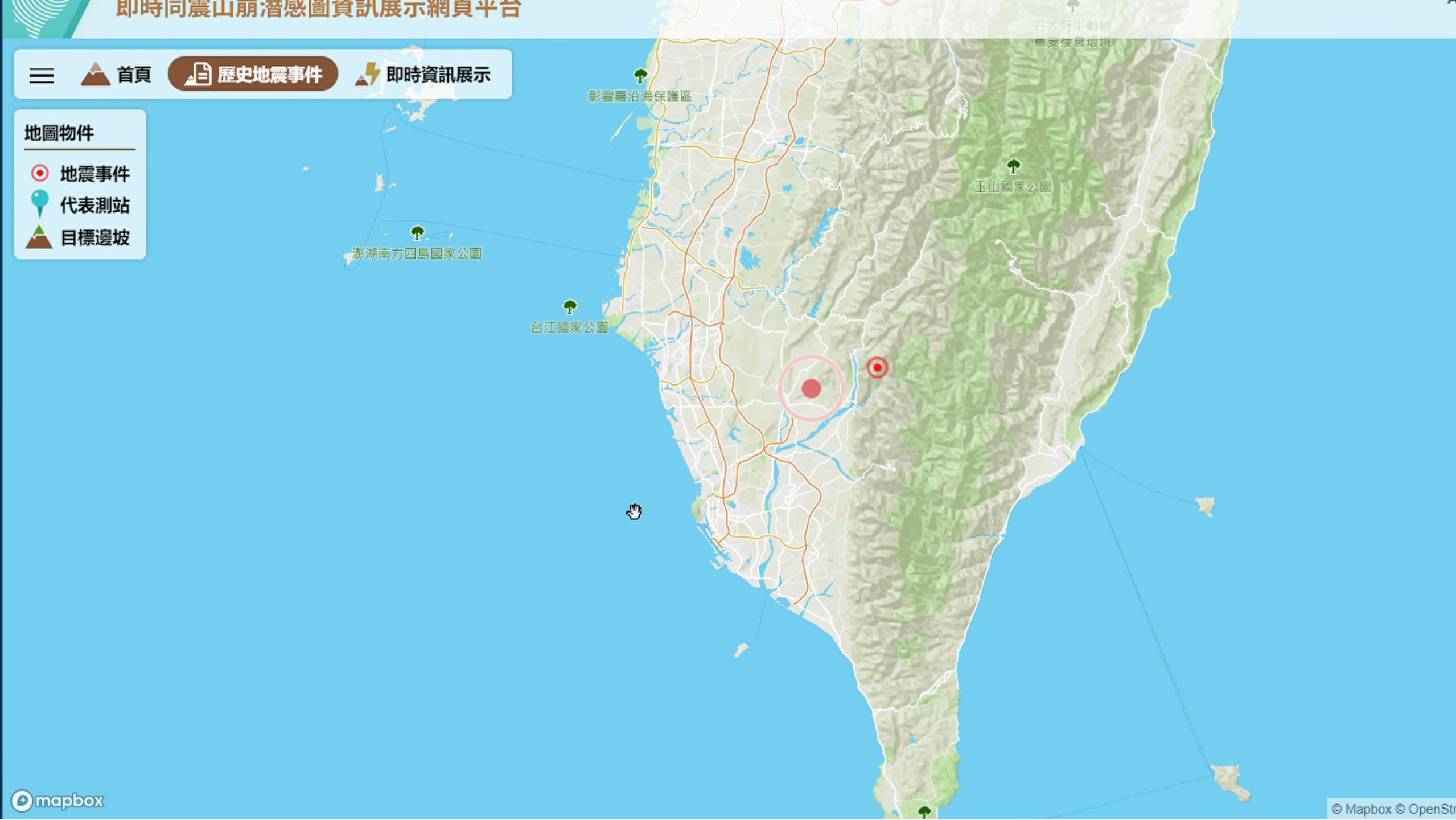
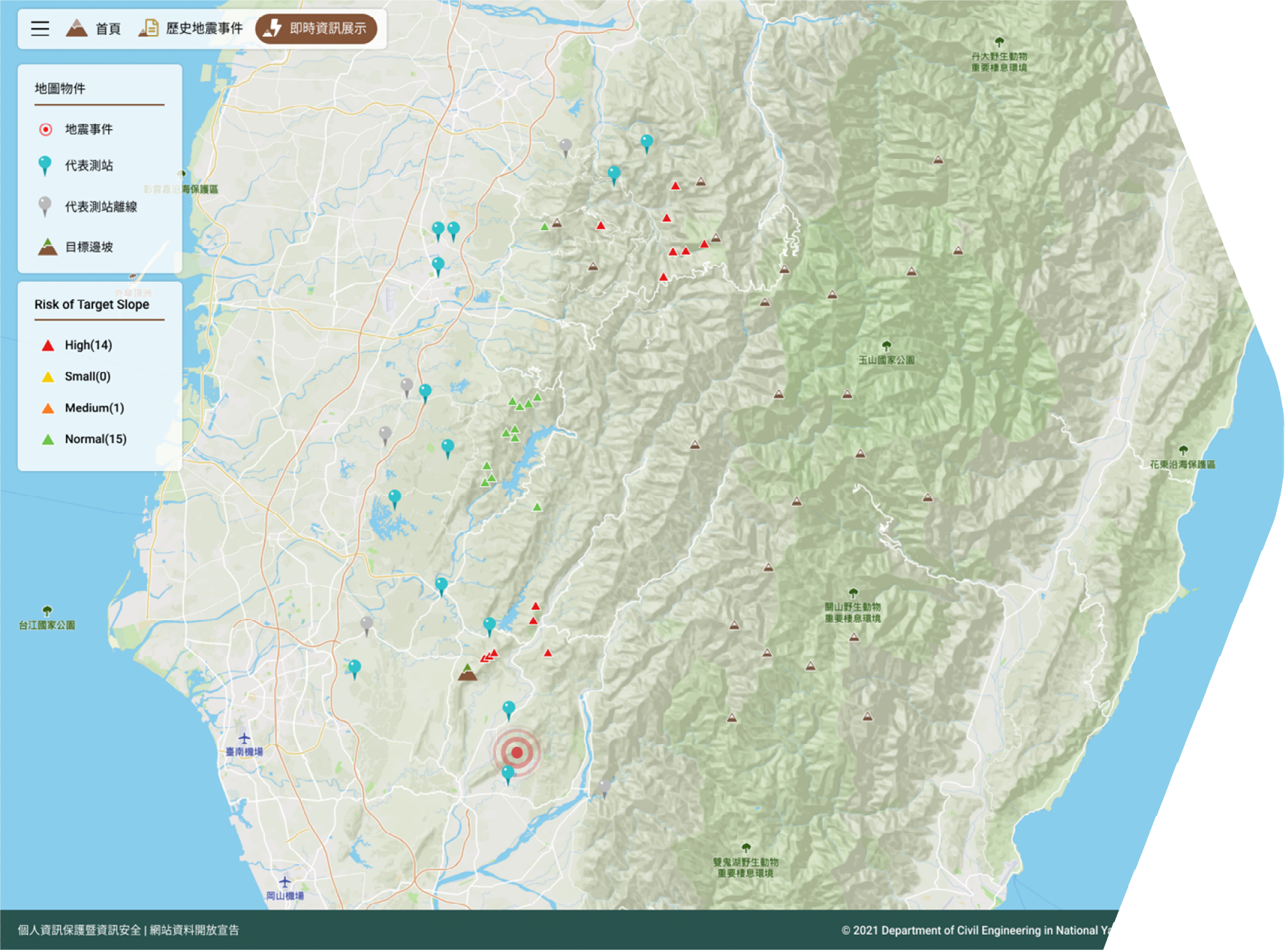
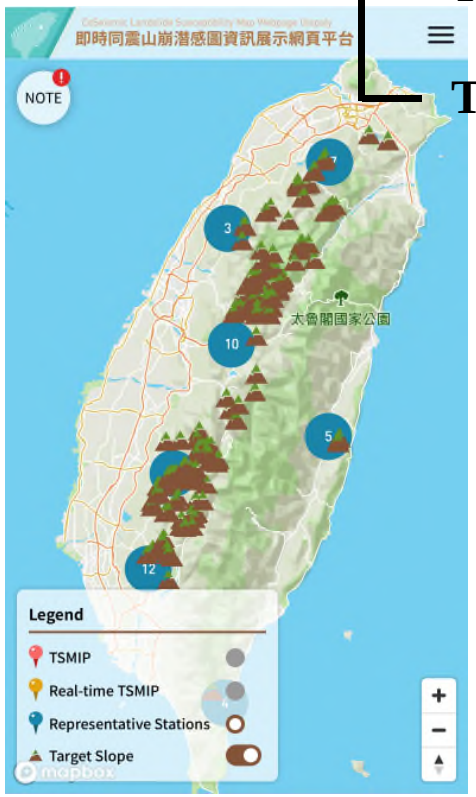
即時TSMIP
代表測站
邊坡
21
4
12
6
3
4
10
1
6
5
11
4
太魯閣國家公園
mapbox
© Mapbox © OpenStreetMap


即時同震山崩潛感圖資訊展示網頁平台
首頁
歷史地震事件
即時資訊展示
地圖物件
地震事件
代表測站
目標邊坡
彰雲嘉沿海保護區
玉山國家公園
澎湖南方四島國家公園
台江國家公園
mapbox
© Mapbox © OpenStr

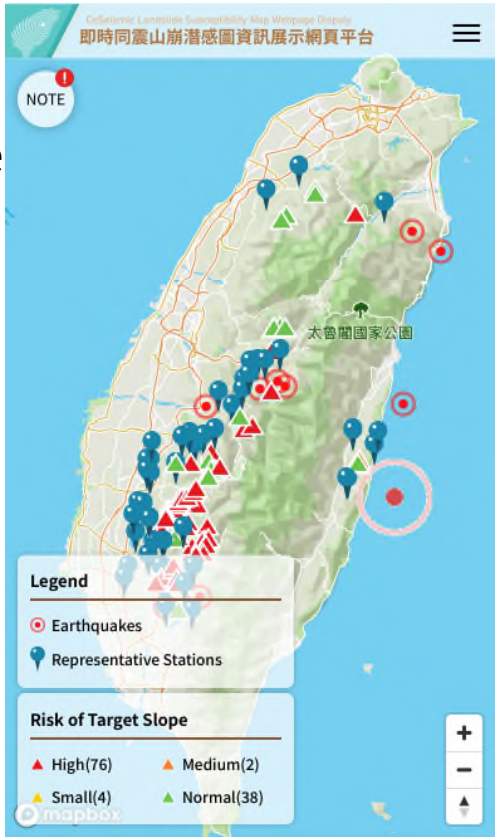

首頁
歷史地震事件
即時資訊展示
地圖物件
地震事件
代表測站
代表測站離線
目標邊坡
Risk of Target Slope
High(14)
Small(0)
Medium(1)
Normal(15)
丹大野生動物
重要棲息環境
玉山國家公園
花東沿海保護區
關山野生動物
重要棲息環境
雙鬼湖野生動物
重要棲息環境
台江國家公園
臺南機場
岡山機場
個人資訊保護暨資訊安全 | 網站資料開放宣告
© 2021 Department of Civil Engineering in National Y

Web-based Display System

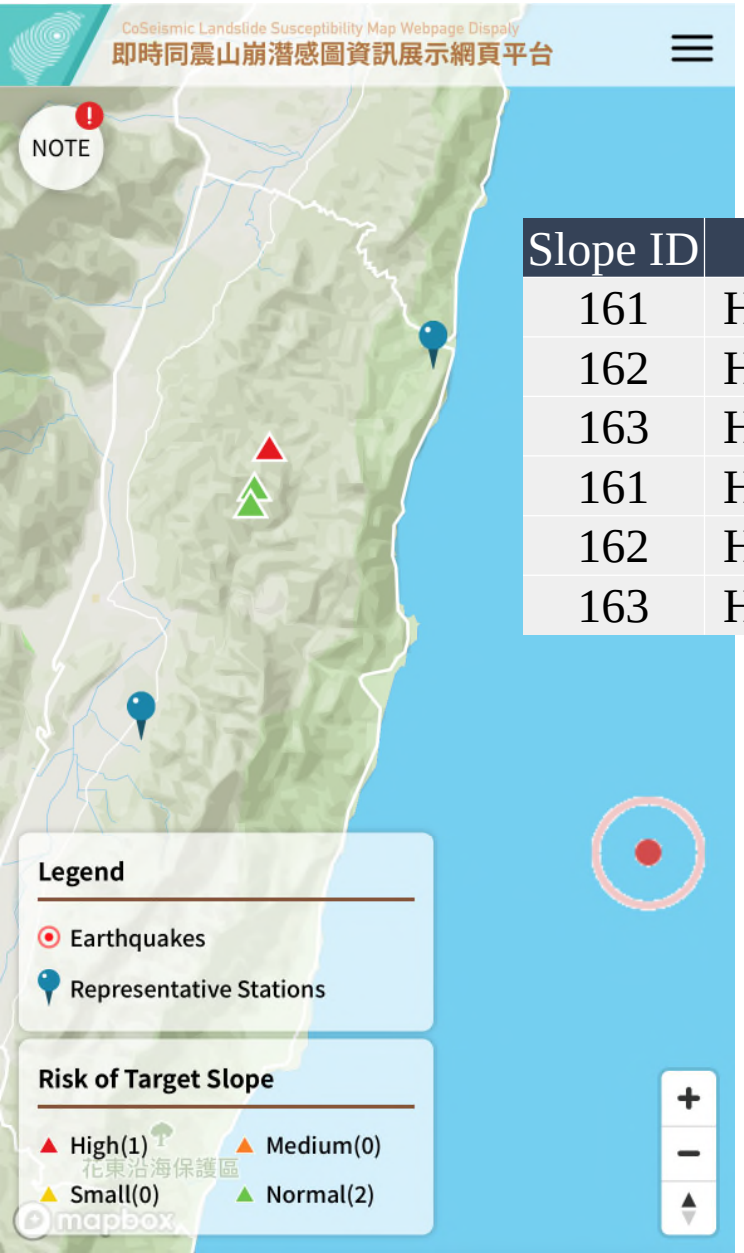
- **Home**
  - TSMIP
  - Real-time TSMIP
  - Representative Stations
  - Target Slope
- **Historical Earthquakes**
  - Earthquakes
  - Representative Stations
  - Risk of Target Slope
    - Red
    - Orange
    - Yellow
    - Green
- **Real-Time Displays**







Case: March 22 2022 Hualien Earthquake



Slope ID	Station	D10 (cm)	PGA (gal)	PGV (cm/s)	Strike (°)	Epi. (km)	Azi. (°)	Collapse	Prediction
161	HWA002	984	210.04	8.72	41	18.6	0	no	no
162	HWA002	1229	210.04	8.72	51	18.6	0	no	no
163	HWA002	1108	210.04	8.72	51	18.6	0	no	no
161	HWA037	970	323.86	35.42	41	13.1	281	no	yes
162	HWA037	1212	323.86	35.42	51	13.1	281	no	no
163	HWA037	1093	323.86	35.42	51	13.1	281	no	no

All Area C5.0/CART Decision Tree Confusion Matrix

Accuracy = 83.3% FNR = 0%

	Observed YES	Observed NO
Predicted YES	**0**	**1**
Predicted NO	**0**	**5**

2022 Sep EQ series
舞鶴崩塌地Newmark分析測試

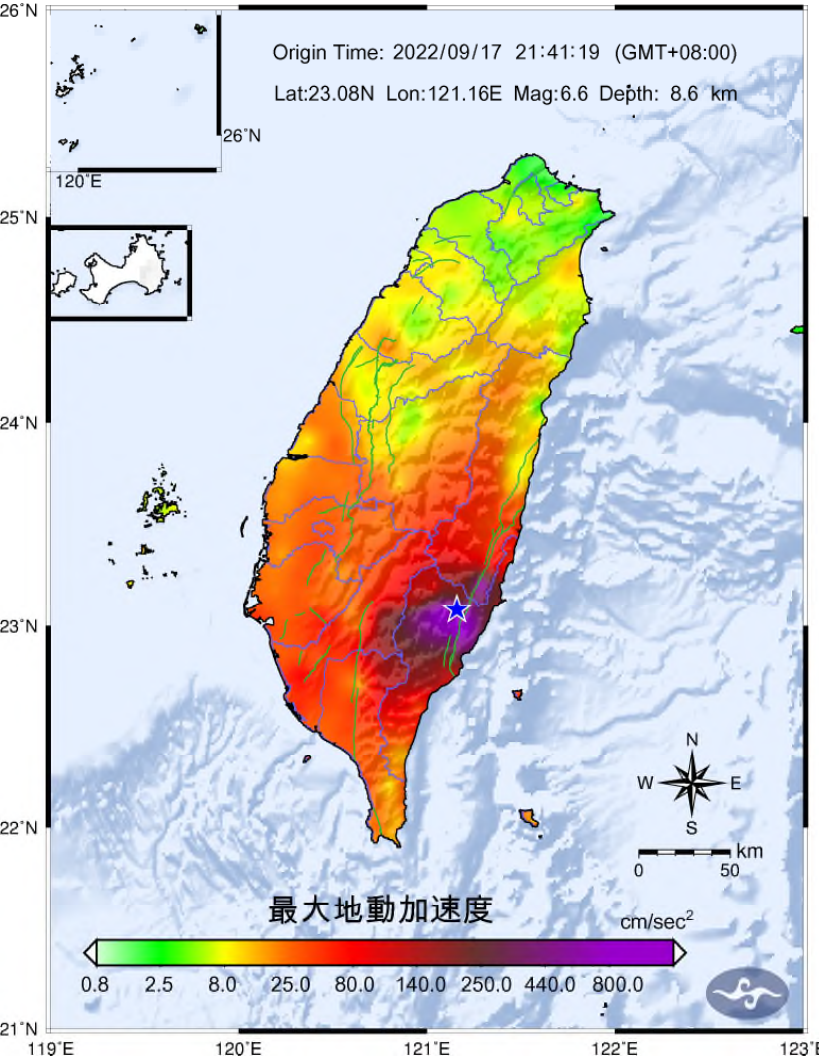
Tz-shin Lai, Wei-An Chao, Che-Ming Yang

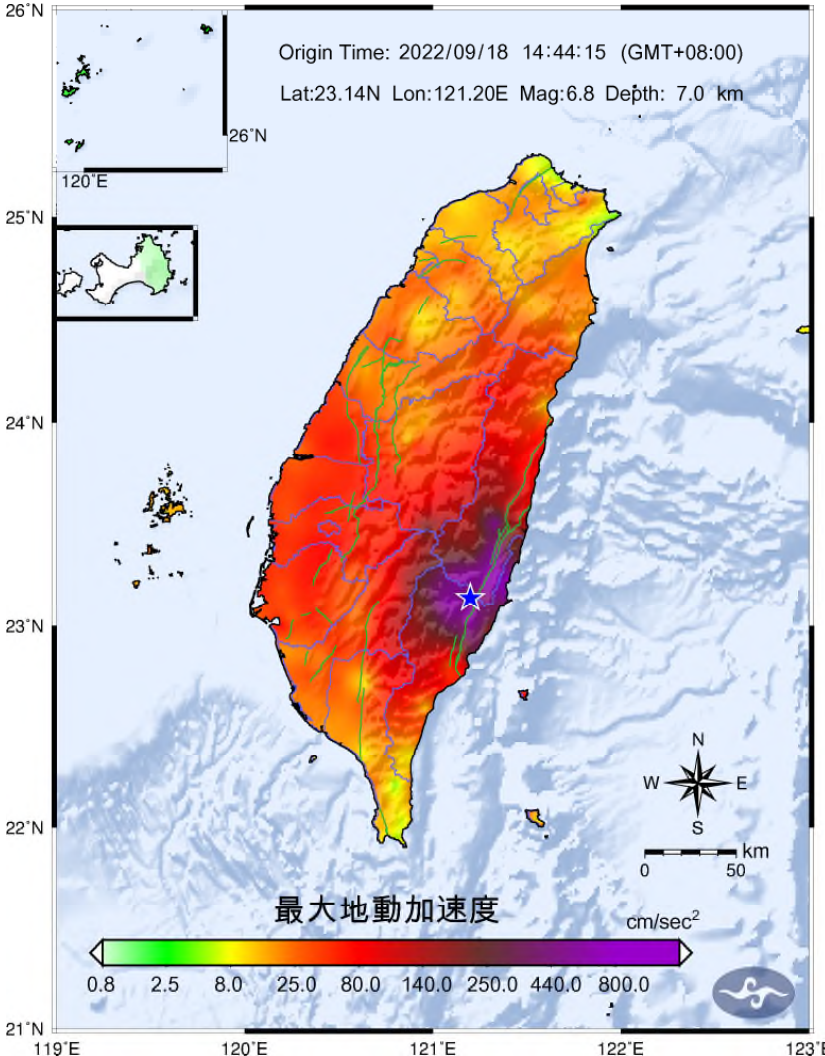


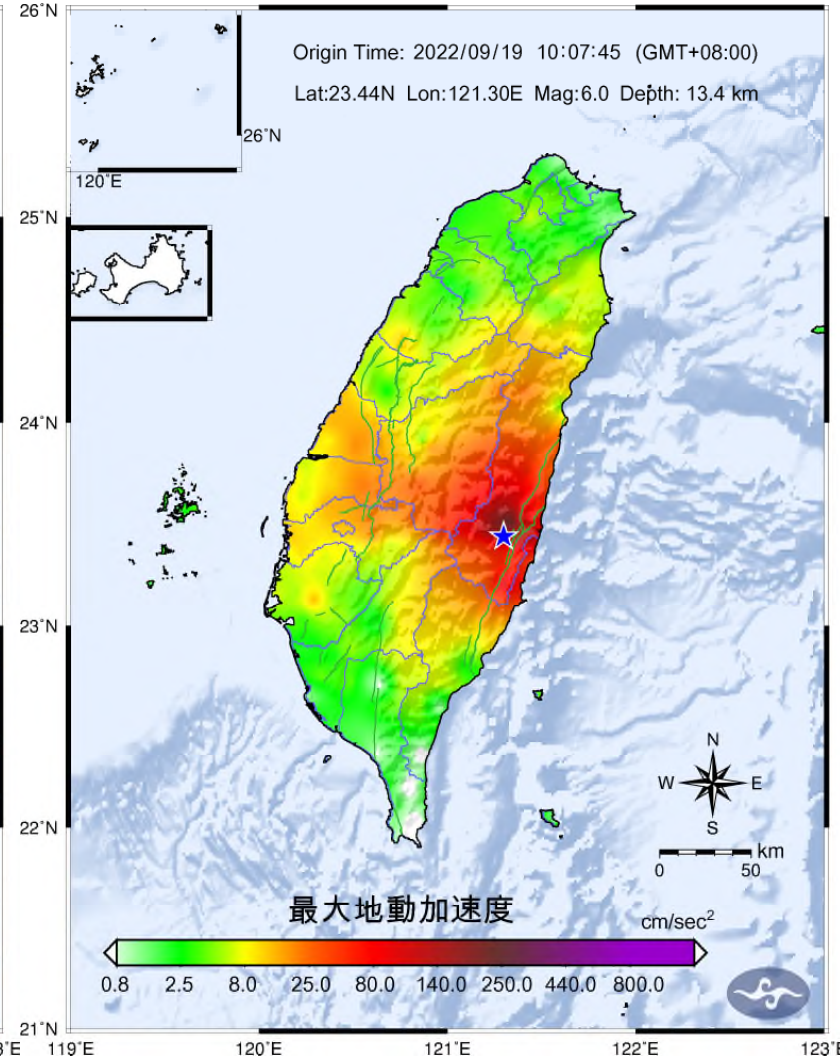
•第086號
•發震時間： 111年9月17日 21:41:19
•地震深度： 8.6 km
•芮氏規模： 6.6
•相對位置： 臺東縣政府北方 36.4 km

•第111號
•發震時間： 111年9月18日 14:44:15
•地震深度： 7.8 km
•芮氏規模： 6.8
•相對位置： 臺東縣政府北方 42.6 km

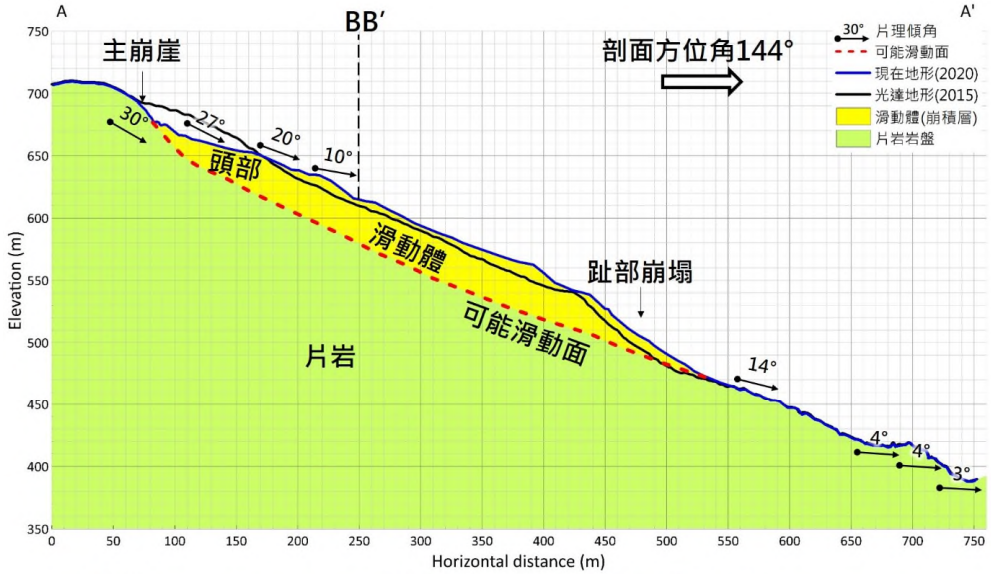
•第137號
•發震時間： 111年9月19日 10:07:45
•地震深度： 13.4 km
•芮氏規模： 6.0
•相對位置： 花蓮縣政府南南西方 69.1 km

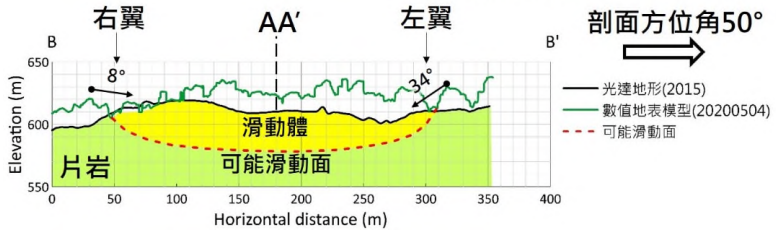


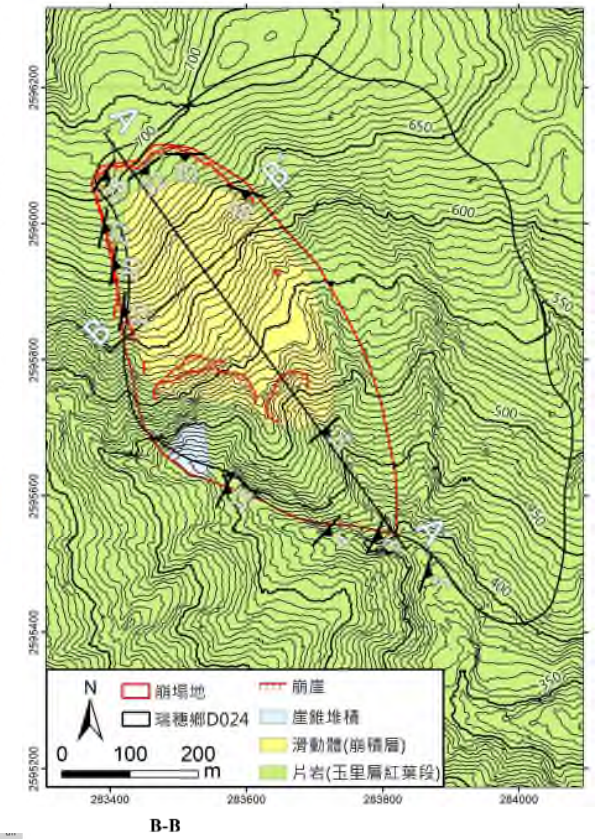


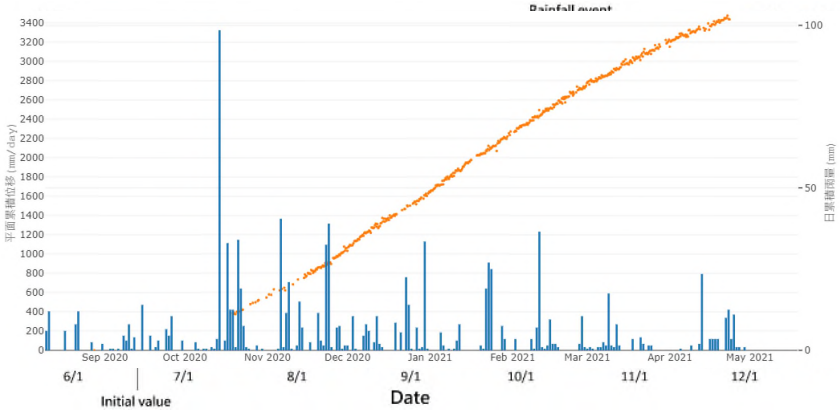


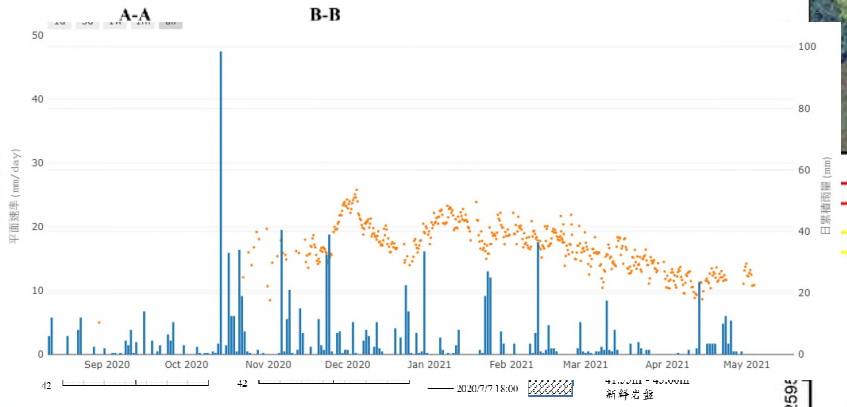
Potential Large-Scale Landslide Area - Ruisui D024

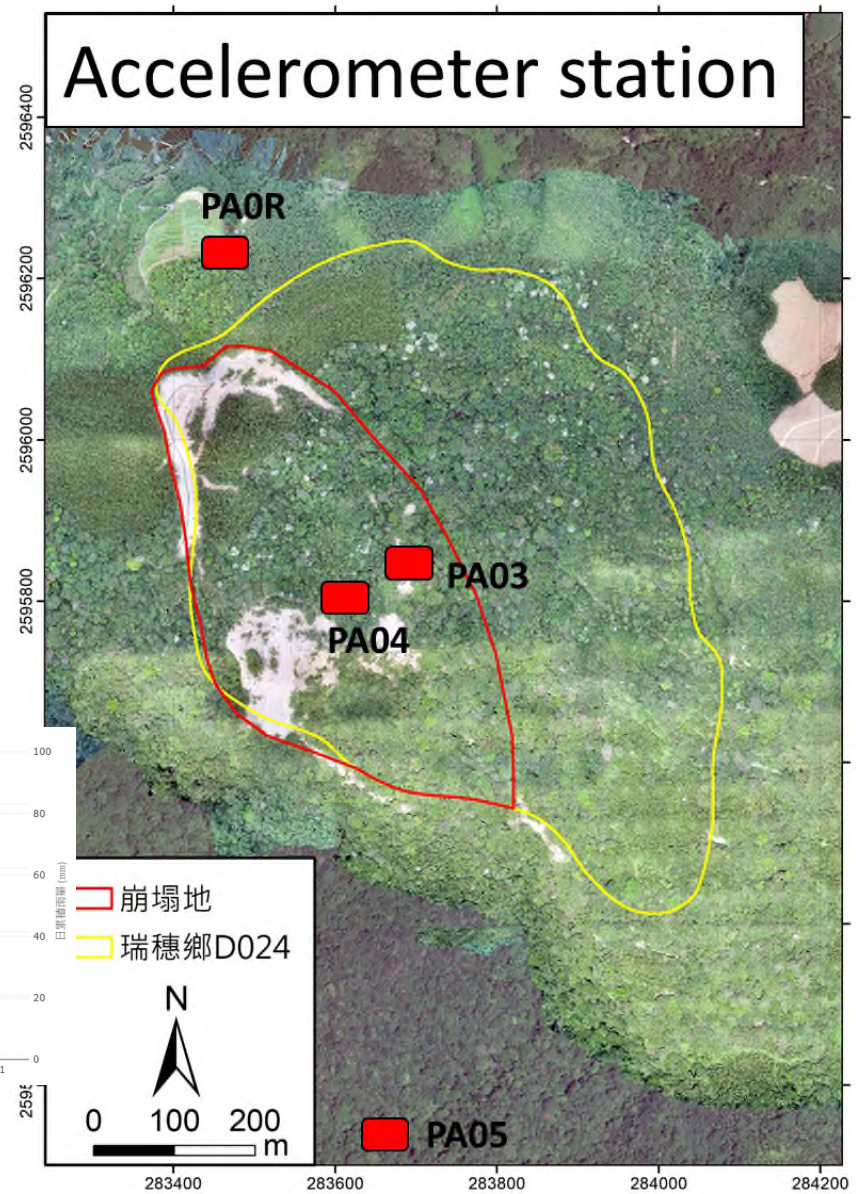






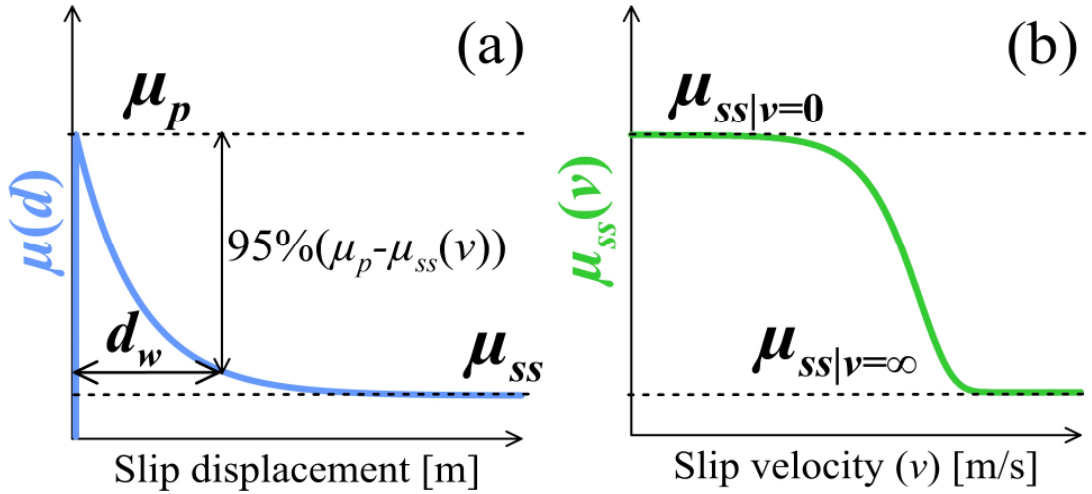






舞鶴崩塌地摩擦力學參數

- 54.0 # str- Strike of sliding plane relative to North
- 24.0 # dip- Dip of sliding plane
- 0.44 # ur- residual friction coefficient
- 0.55 # up- peak friction coefficient
- 0.15 # us- steady-state friction coefficier
- 11.0 # Dw- Critical distance [m]
- 0.396 # Vc- Critical velocity [m/s]



$$\mu(d) = \mu_{ss} + (\mu_p - \mu_{ss})\exp(\ln(0.05)d/d_w)$$

$$\mu_{ss}(v) = \mu_{ss|v=\infty} + (\mu_{ss|v=0} - \mu_{ss|v=\infty})\exp(-v^A/V_C)$$

關山地震0917

關山地震0917

測站名稱,最大加速度出現的分量,加速度值,三分量均方根後最大值

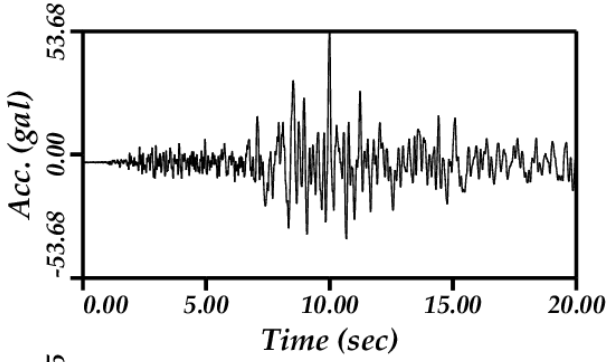
PA0R,EW,-48.92 gal,57.84 gal

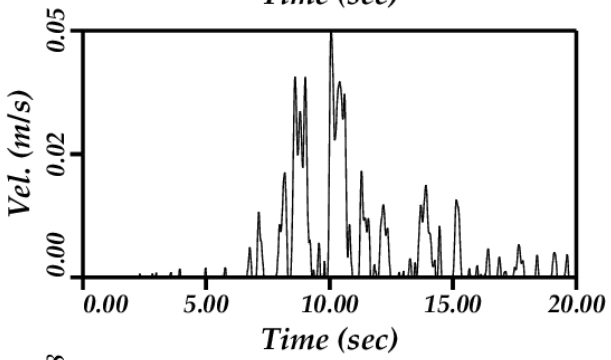
PA03,EW,59.24 gal, 61.40 gal

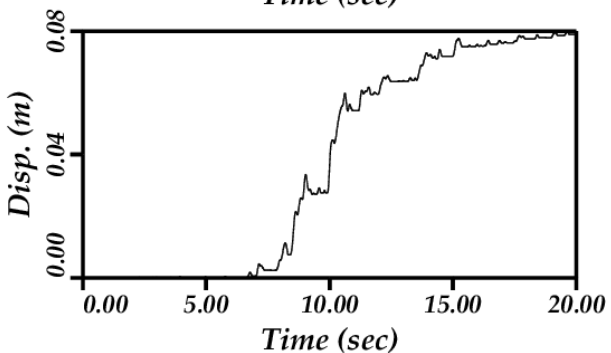
PA04,EW,-52.92 gal, 61.21 gal

PA05,EW, 51.16 gal, 55.32 gal

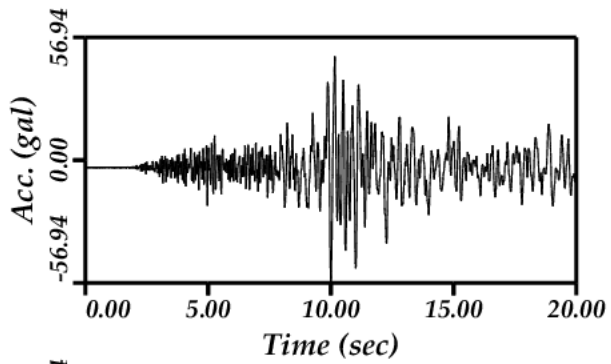
PA0R

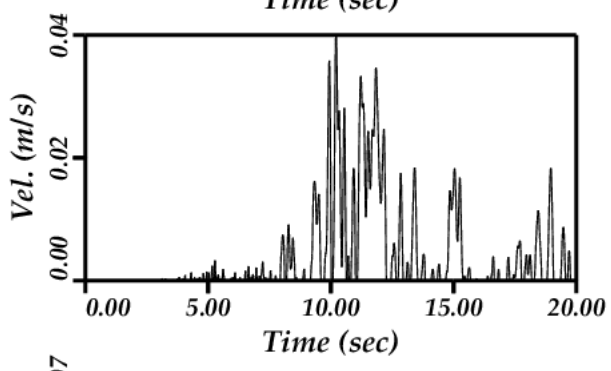


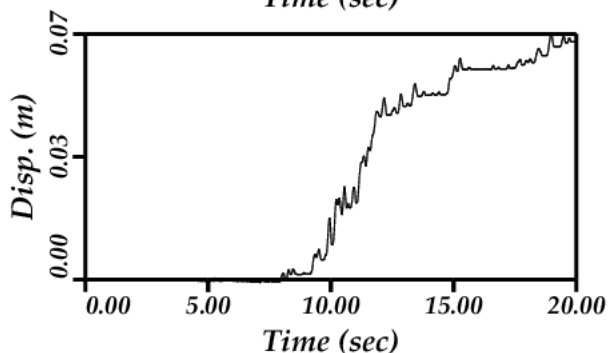




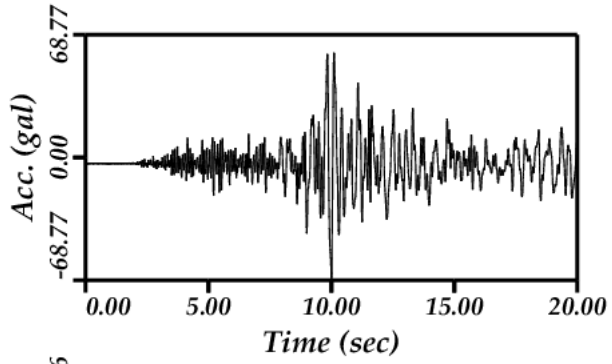
PA03

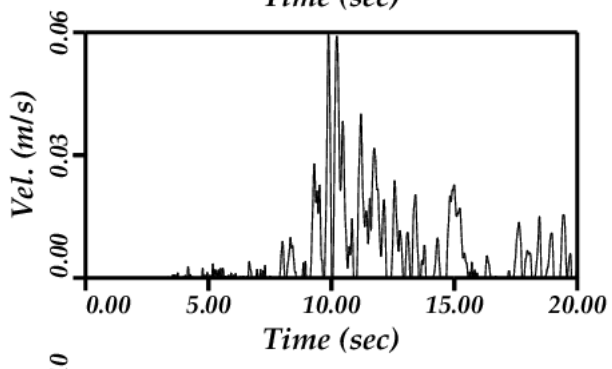


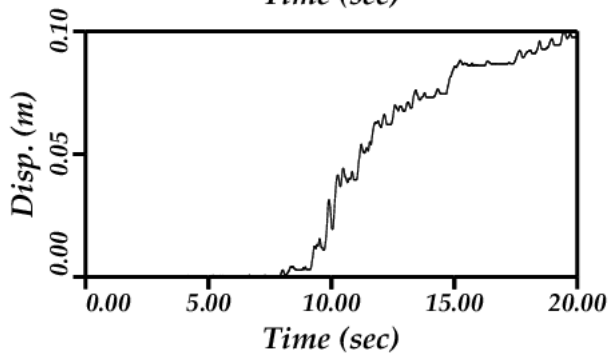




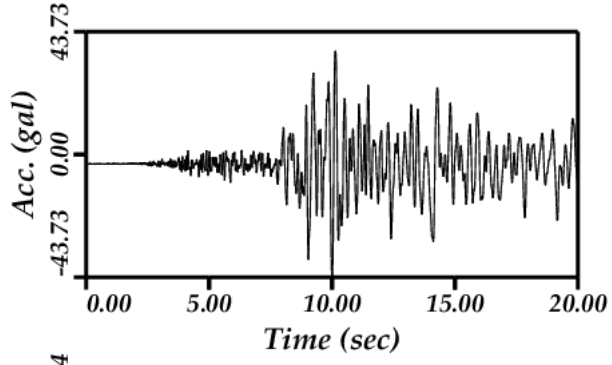
PA04

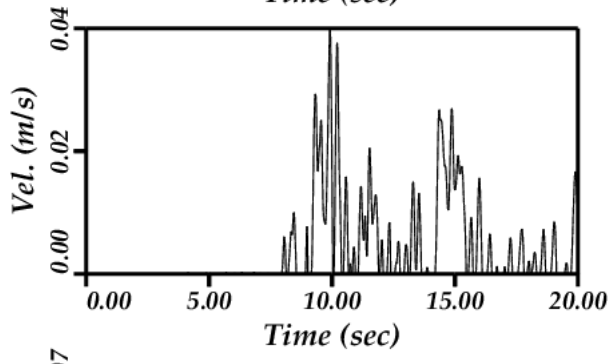


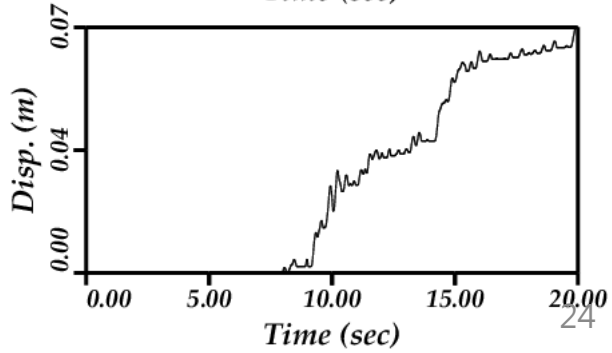




PA05







池上地震0918

池上地震0918

測站名稱,最大加速度出現的分量,加速度值,三分量均方根後最大值

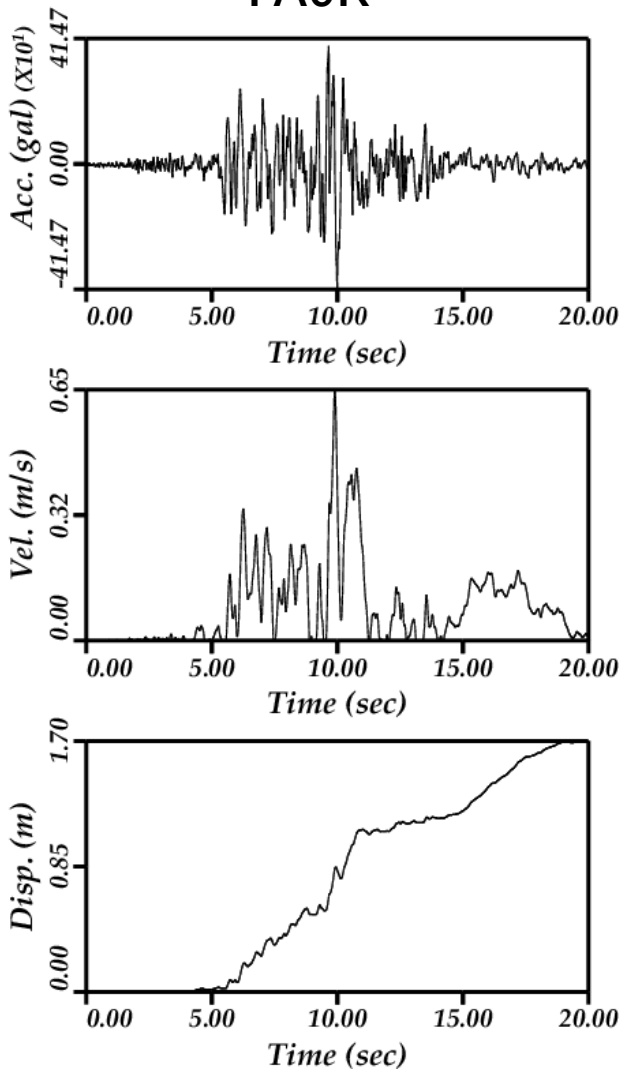
PA0R,EW,419.91 gal, 427.44 gal

PA03,**Z**,279.15 gal, 335.16 gal

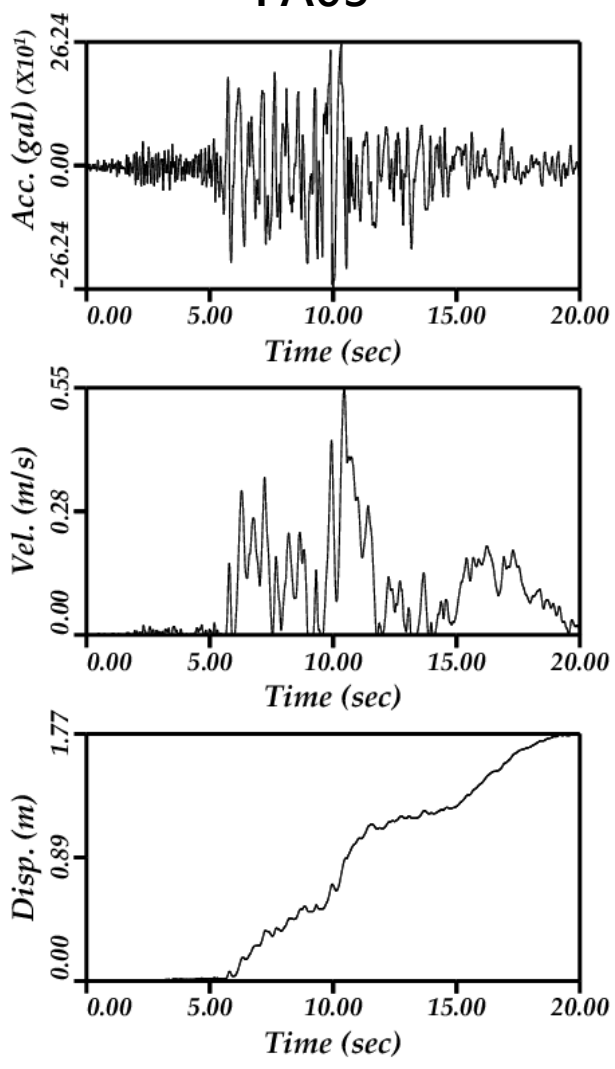
PA04,EW,-408.93 gal, 479.14 gal

PA05,NS,426.04 gal, 430.61 gal

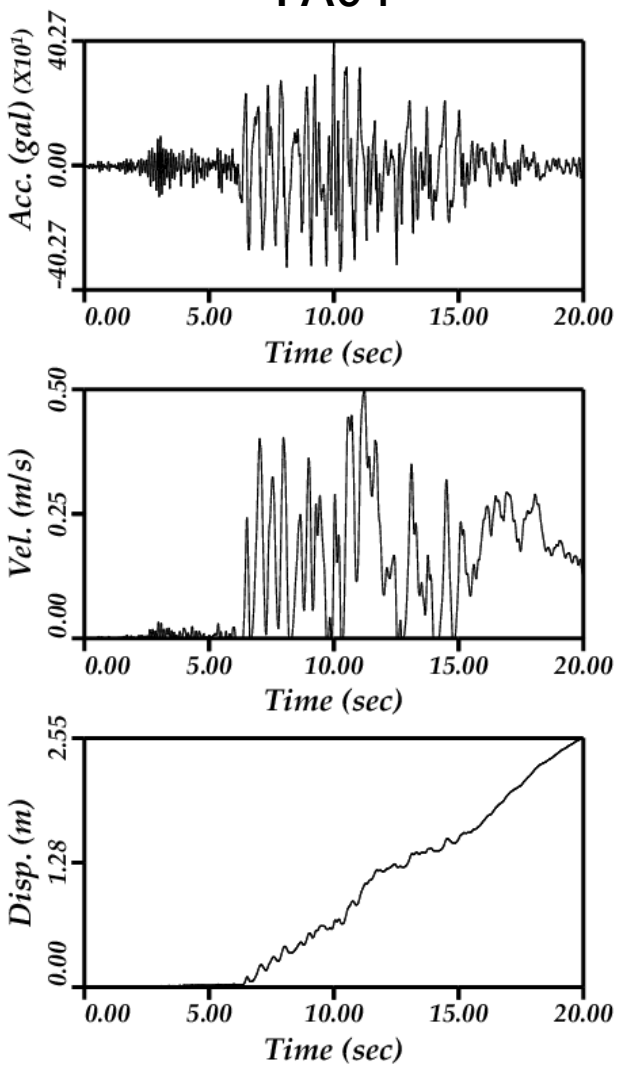
PA0R



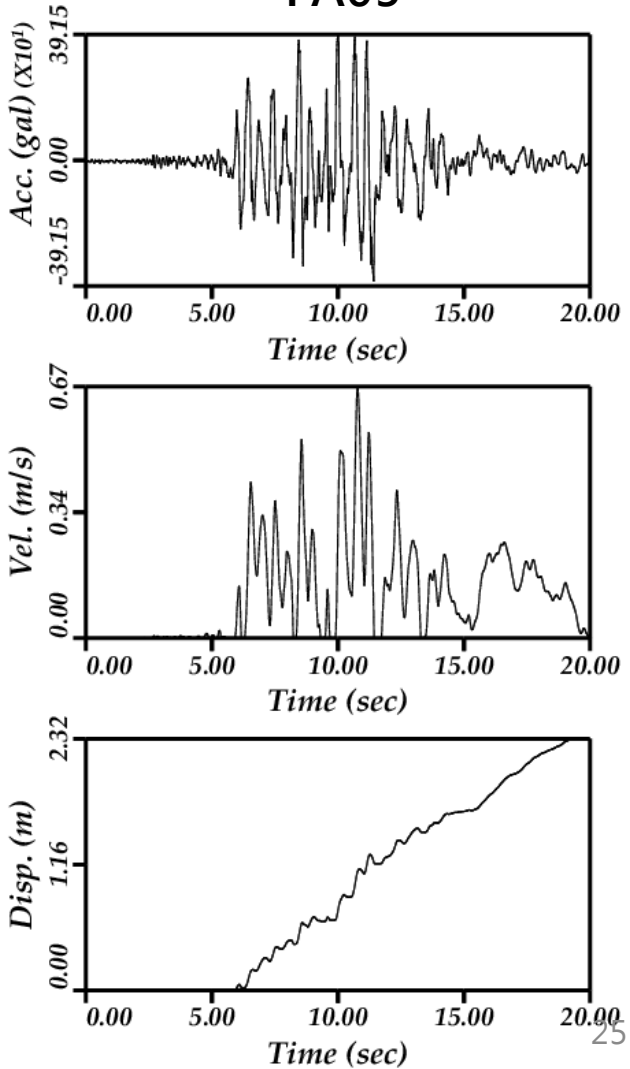
PA03



PA04



PA05



紅葉地震0919

紅葉地震0919

測站名稱,最大加速度出現的分量,加速度值,三分量均方根後最大值

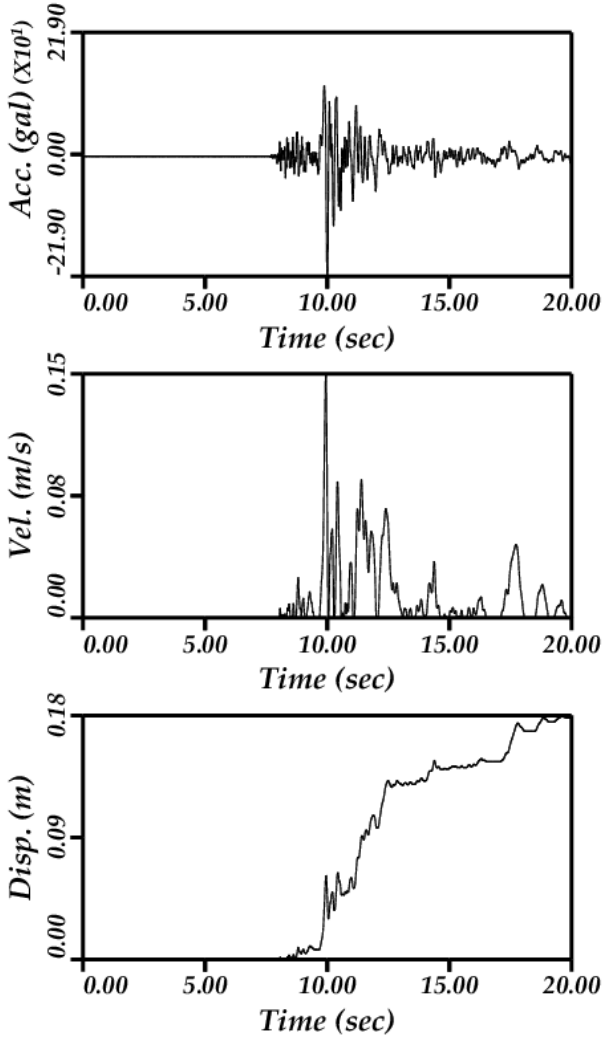
PA0R,EW,-249.78 gal, 278.09 gal

PA03,NS, -265.16 gal, 270.57 gal

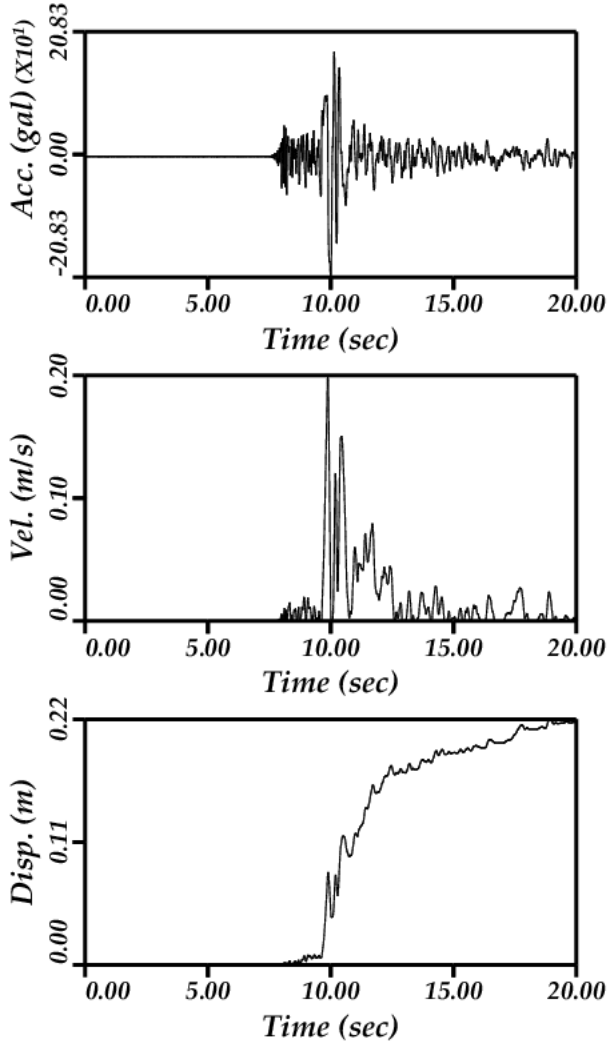
PA05,NS,-372.99 gal, 376.11 gal

PA04缺資料

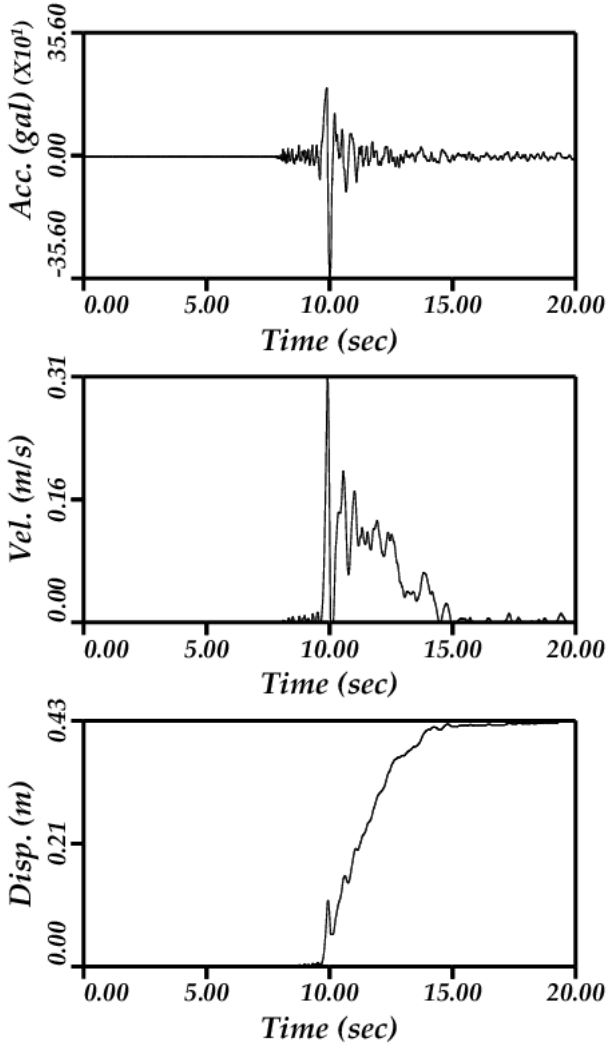
PA0R



PA03



PA05



- **Newmark分析結果**
- 關山地震0917：
- 位移量在0.07-0.10m，PA04為位移量最大的站，d10(10秒內的累積位移量)<10cm，未達崩塌滑動量門檻值。
- 池上地震0918：
- 此地震是對舞鶴地區造成最大位移量，**位移量在1.70-2.55m**，PA04為位移量最大的站達2.55m，PA05為2.32m，已超過崩塌滑動位移量門檻值許多。
- 紅葉地震0919：
- 位移量在0.18-0.43m，PA05為位移量最大的站，PA04缺資料，d10>10cm，超過崩塌滑動位移量門檻值。

小結:

(A)地震波從南方遠處進入舞鶴地區，最大加速度值會出現在東西分量，且在崩塌地區域內測站**PA04**會有較大的加速度數值。

(B)上述觀察，當舞鶴地區的震度等於或大於**5**以後，會更加的顯著(比較關山及池上地震)。

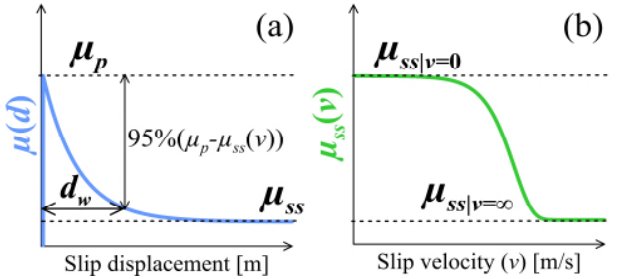
(C)測站PA03在關山地震及池上地震在最大加速度值分量及加速度值的特性存在極大的差異，可能原因為該測站位置鄰近崩塌邊界。

(D)紅葉地震與0917及0918的各站加速度值特徵有顯著差異，主要原因還是受控於該地震發生在瑞穗，各站的加速度值大小直接是受控於測站與地震的距離影響。

0918池上地震

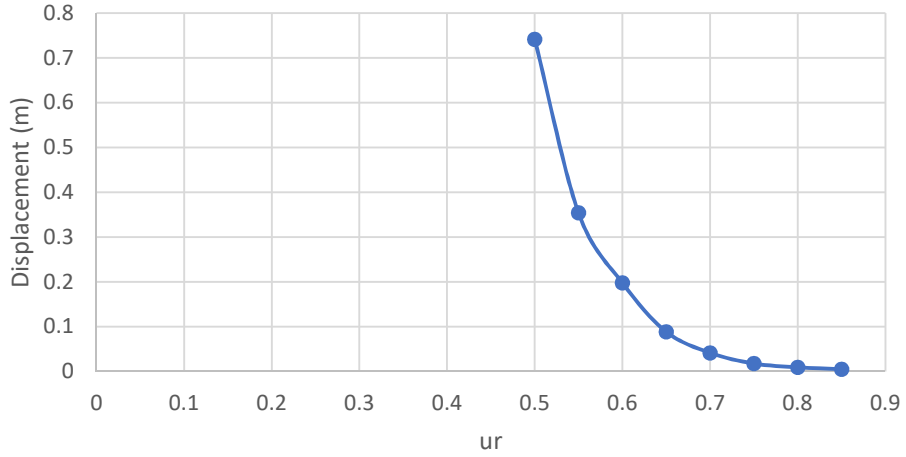
$$\mu(d) = \mu_{ss} + (\mu_p - \mu_{ss})\exp(\ln(0.05)d/d_w)$$

$$\mu_{ss}(v) = \mu_{ss|v=\infty} + (\mu_{ss|v=0} - \mu_{ss|v=\infty})\exp(-v^A/V_C)$$



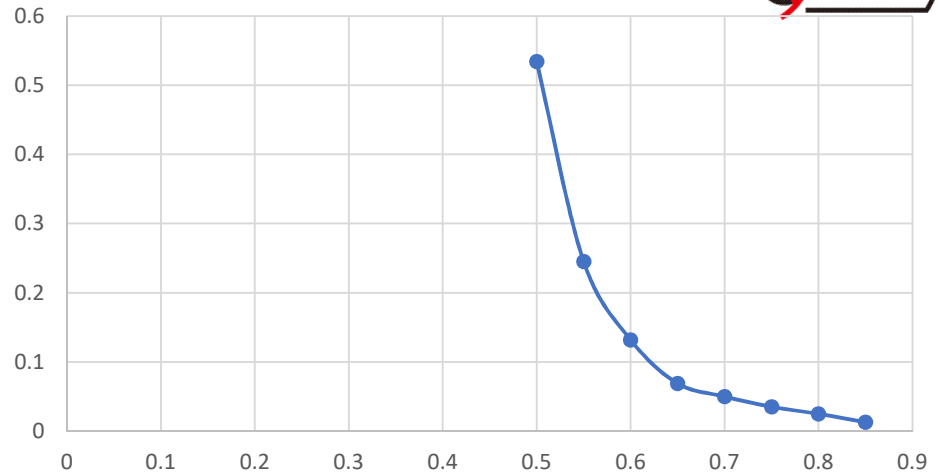
PA04

ur	d(m)
0.5	0.741
0.55	0.354
0.6	0.198
0.65	**0.089**
0.7	0.042
0.75	0.018
0.8	0.0095
0.85	0.0052



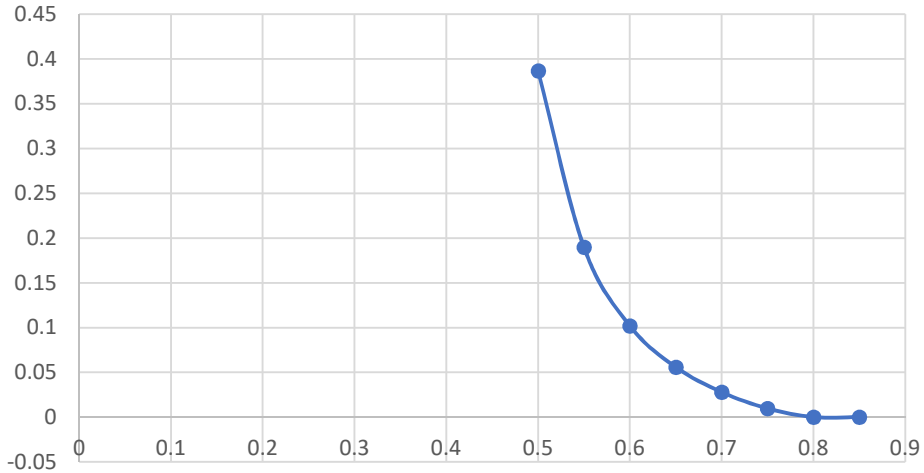
PA0R

ur	d(m)
0.5	0.534
0.55	0.245
0.6	0.132
0.65	**0.069**
0.7	0.05
0.75	0.035
0.8	0.025
0.85	0.013



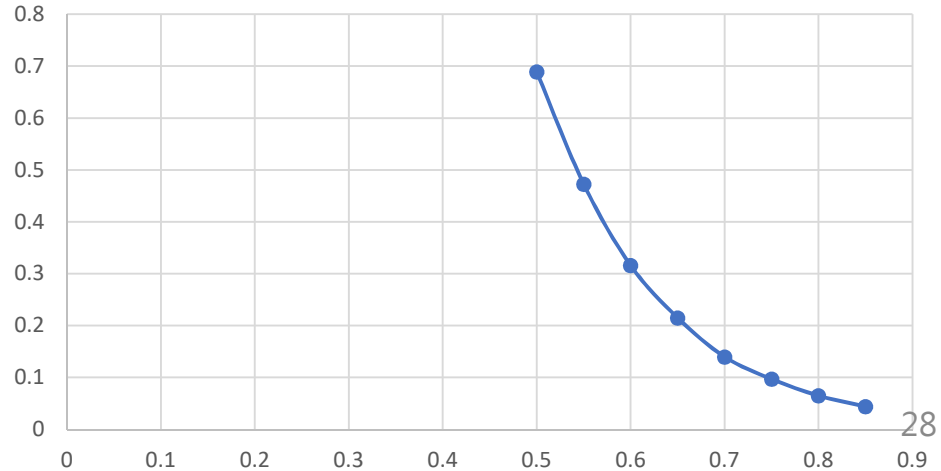
PA03

ur	d(m)
0.5	0.387
0.55	0.19
0.6	**0.102**
0.65	0.056
0.7	0.028
0.75	0.0097
0.8	0.0002
0.85	0



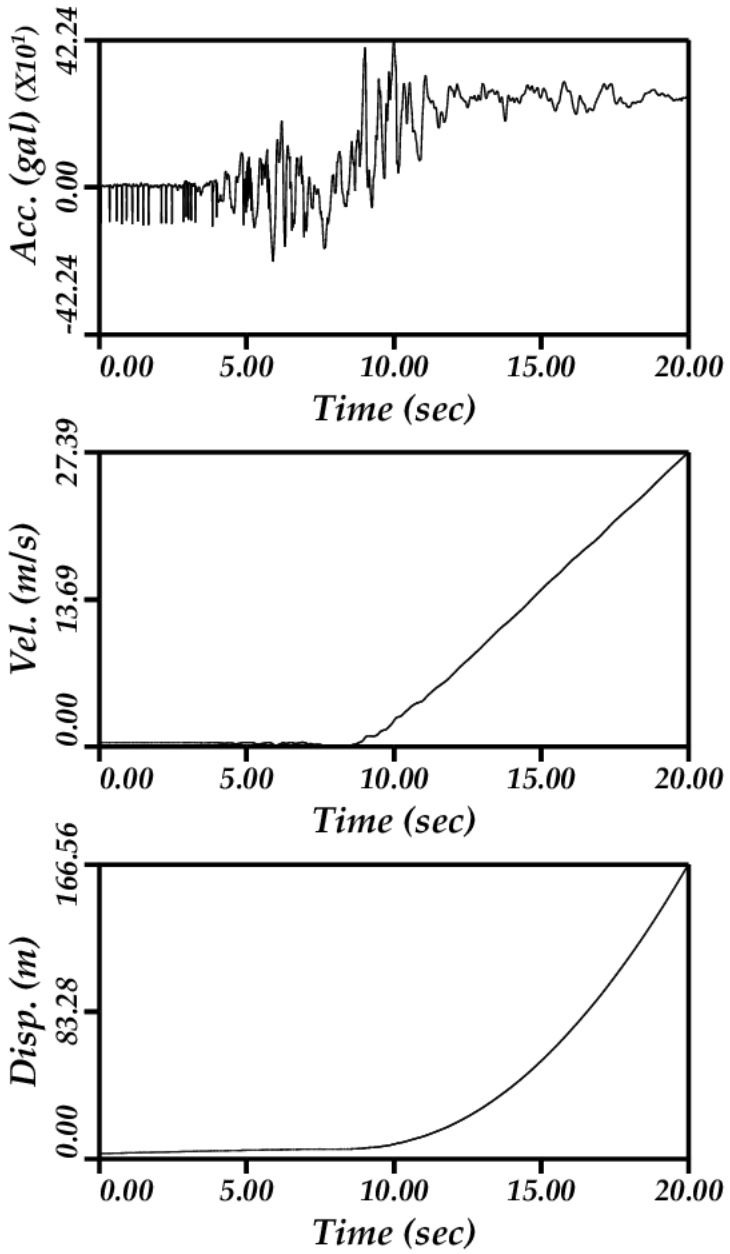
PA05

ur	d(m)
0.5	0.689
0.55	0.473
0.6	0.316
0.65	0.215
0.7	0.14
0.75	**0.097**
0.8	0.065
0.85	0.044

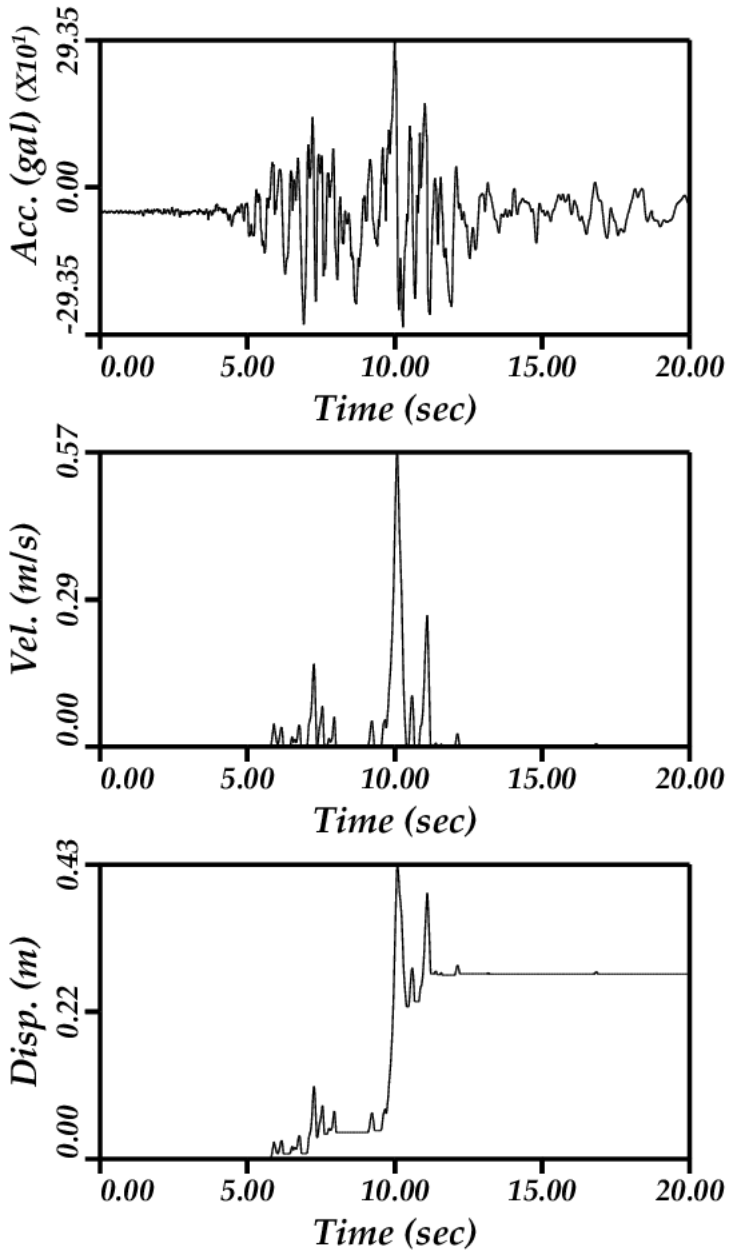


HWA036 瑞穗國小

ur=0.44

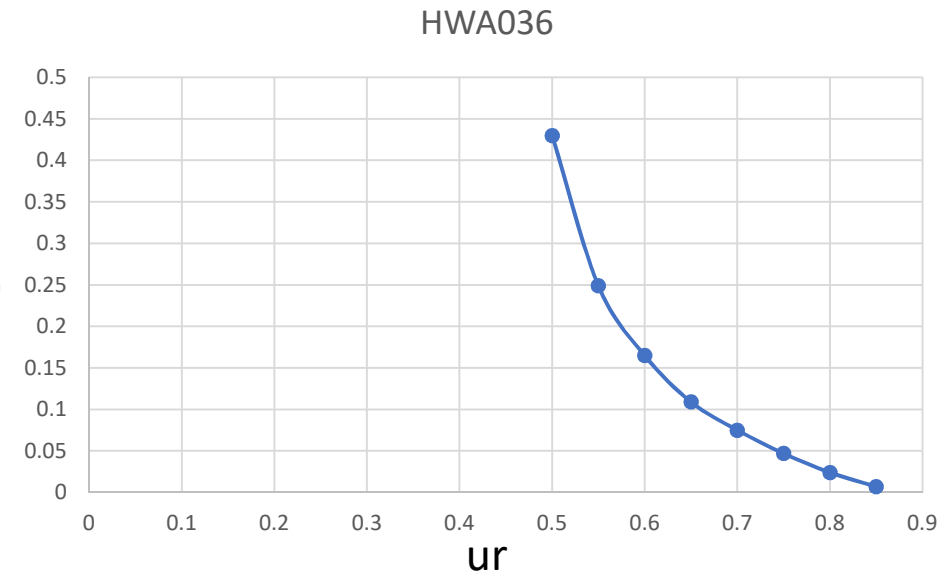


ur=0.5



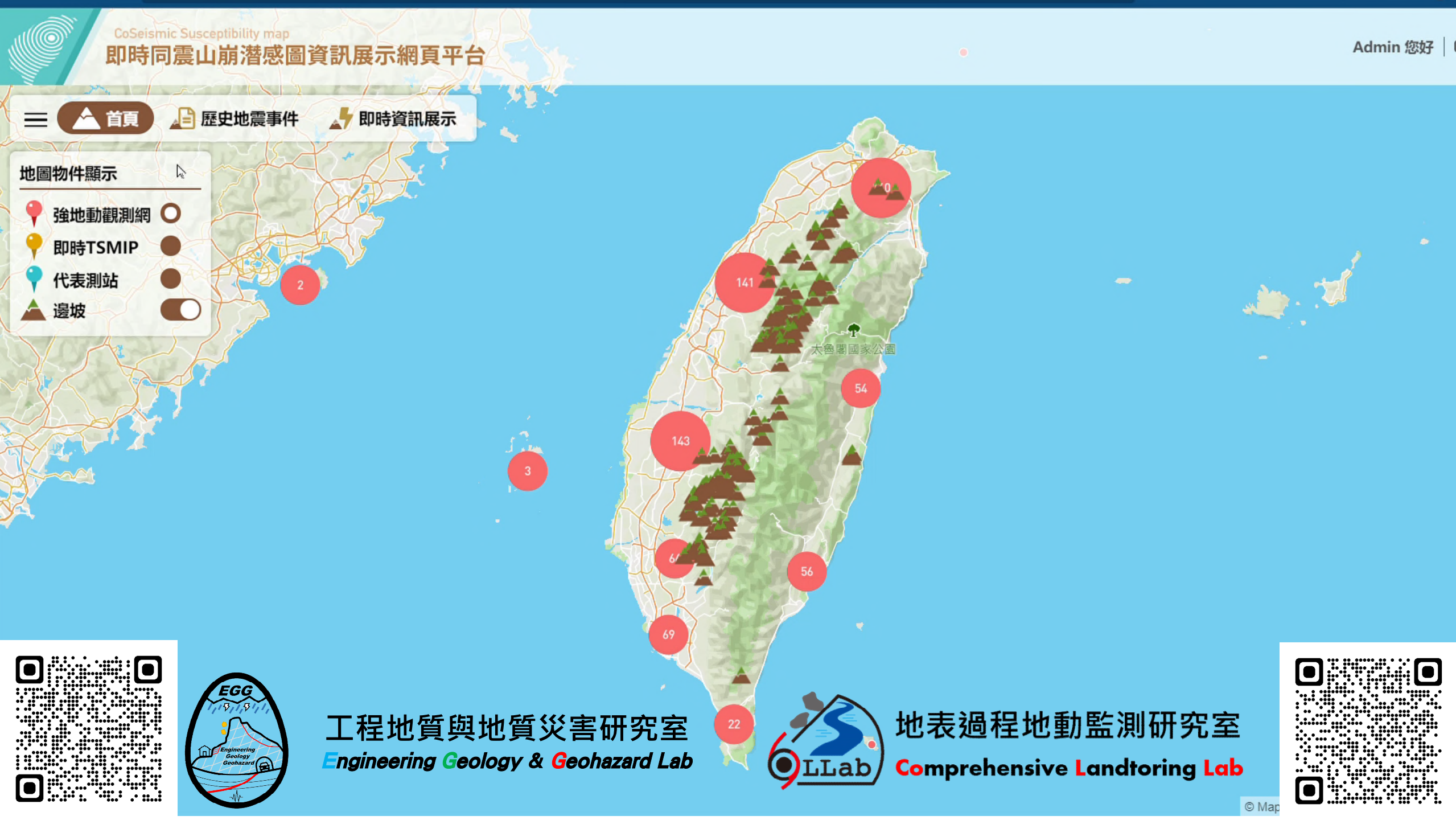
ur	d(m)
0.5	0.43
0.55	0.249
0.6	0.165
0.65	**0.109**
0.7	0.075
0.75	0.047
0.8	0.024
0.85	0.007

d(m)



Could the coseismic displacement be detected by the monitoring of GNSS, UAV DSM, SAR…?




CoSeismic Susceptibility map
即時同震山崩潛感圖資訊展示網頁平台
Admin 您好
首頁
歷史地震事件
即時資訊展示
地圖物件顯示
強地動觀測網
即時TSMIP
代表測站
邊坡
2
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0
54
143
64
56
69
22
太魯閣國家公園
工程地質與地質災害研究室
Engineering Geology & Geohazard Lab
地表過程地動監測研究室
Comprehensive Landtoring Lab
LLab
EGG
Engineering Geology Geohazard