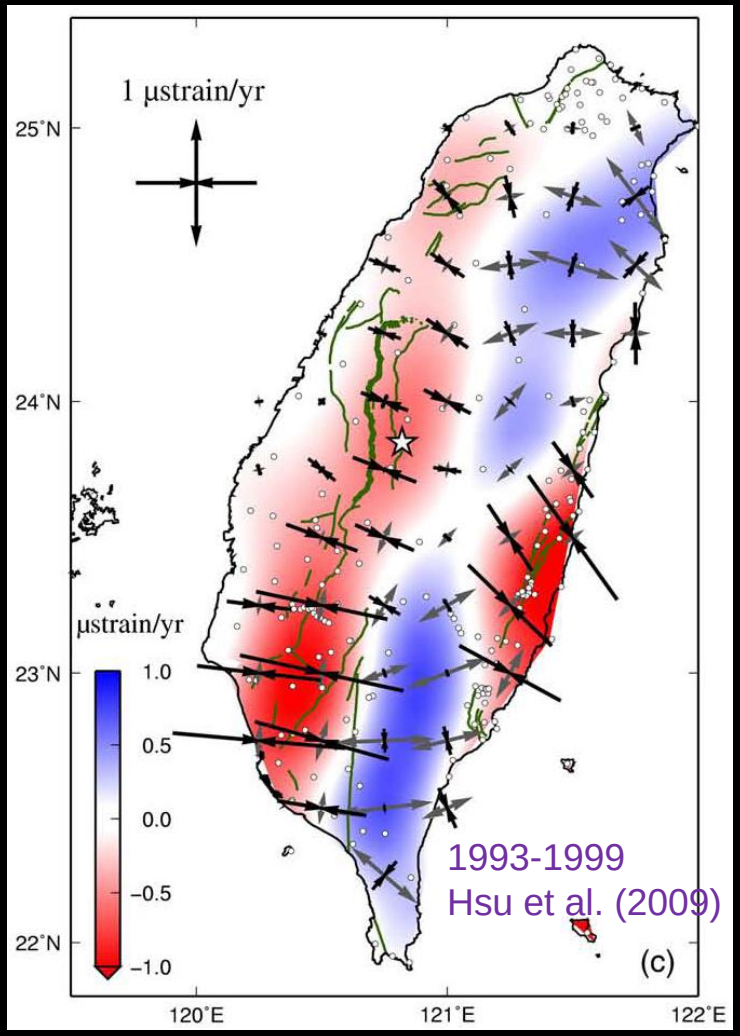
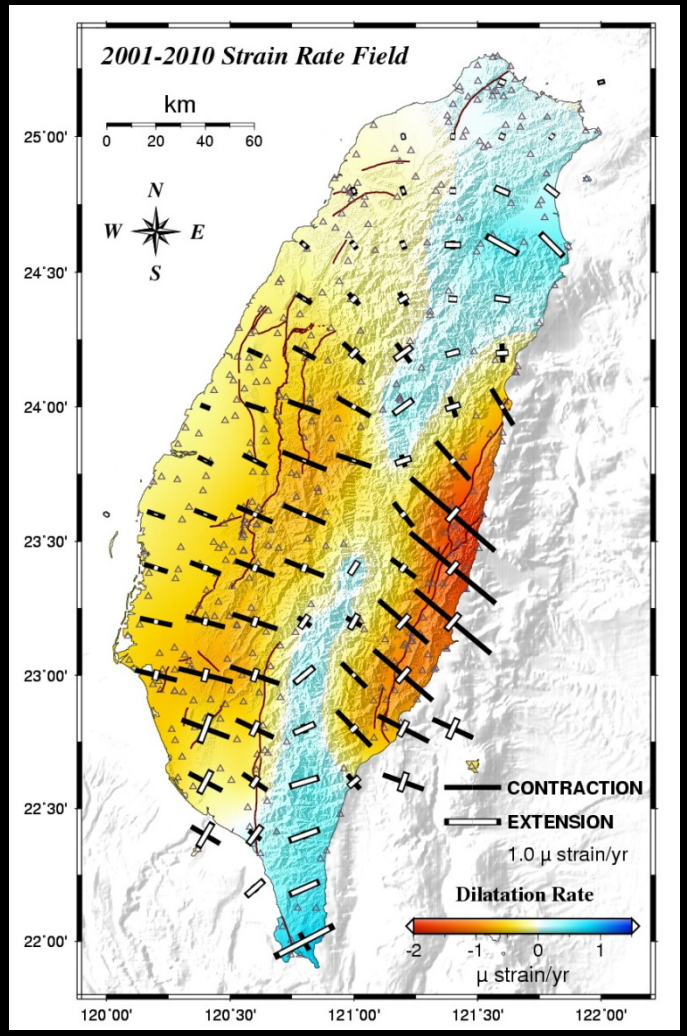
GPS observation and modeling in Taiwan





Ruey-Juin Rau and Kuo-En Ching

National Cheng Kung University, Tainan, Taiwan

Outlines:

1. Why *strain rate* matters in earthquake forecasting?

2. What is the current status of Taiwan strain rate and deformation model?

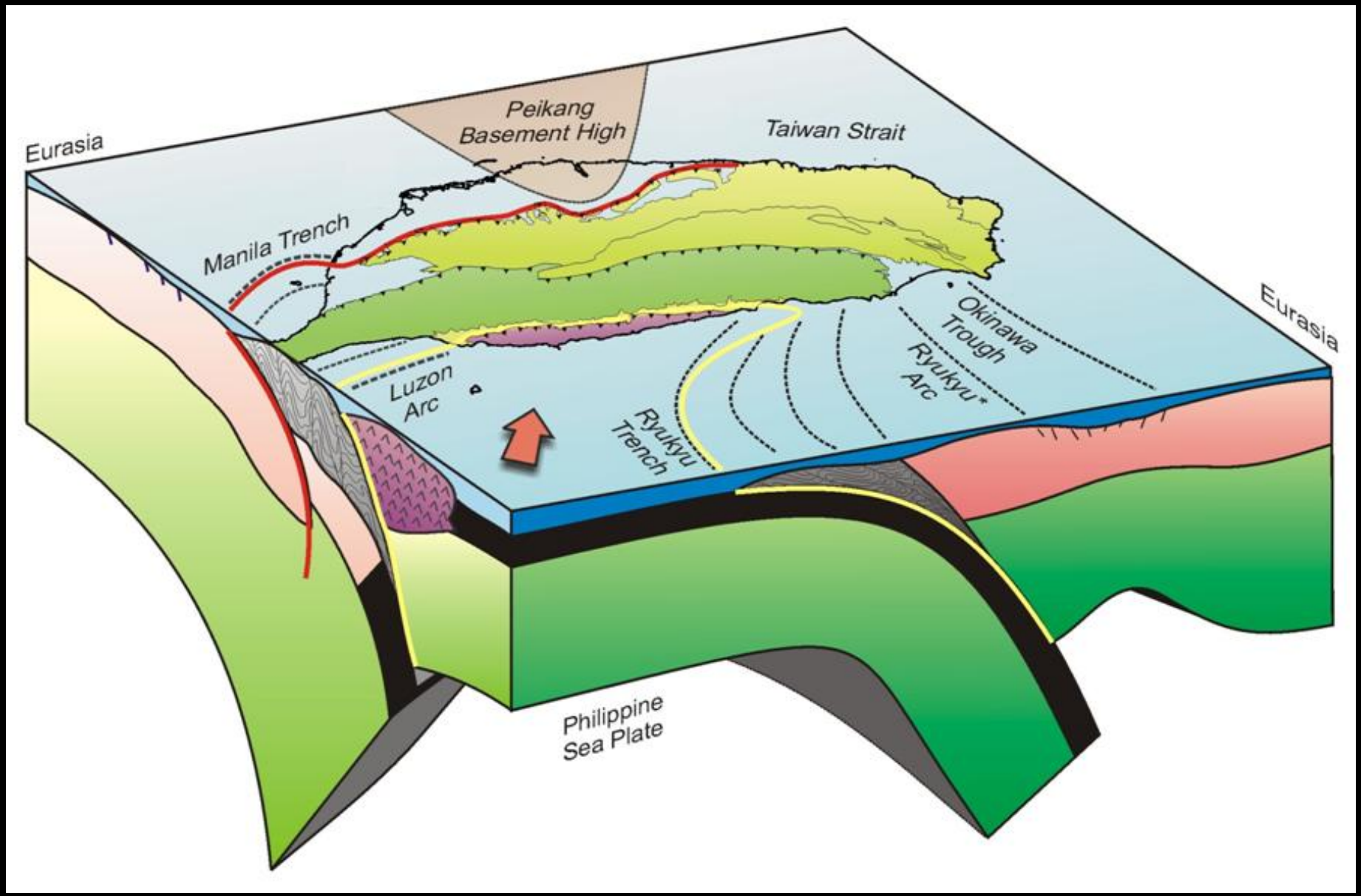
Why *strain rate* matters in earthquake forecasting?

Strain rate reflects elastic stress buildup and effects change in rheology. *Help for earthquake forecast?*

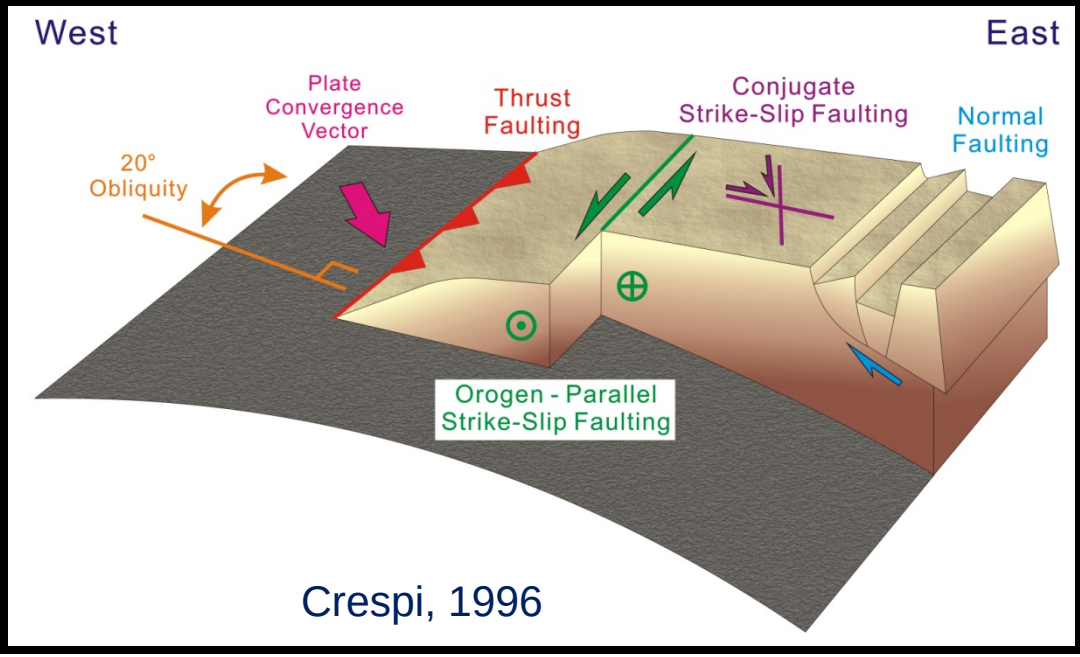
Consider 1.5×10^{-6}/year strain rate for the major thrusts and $3 \times 10^{-5} \sim 3 \times 10^{-4}$ typical coseismic strain drop, the recurrence intervals for large earthquake in Taiwan are 20-200 years.

What is the current status of Taiwan strain rate and deformation model?

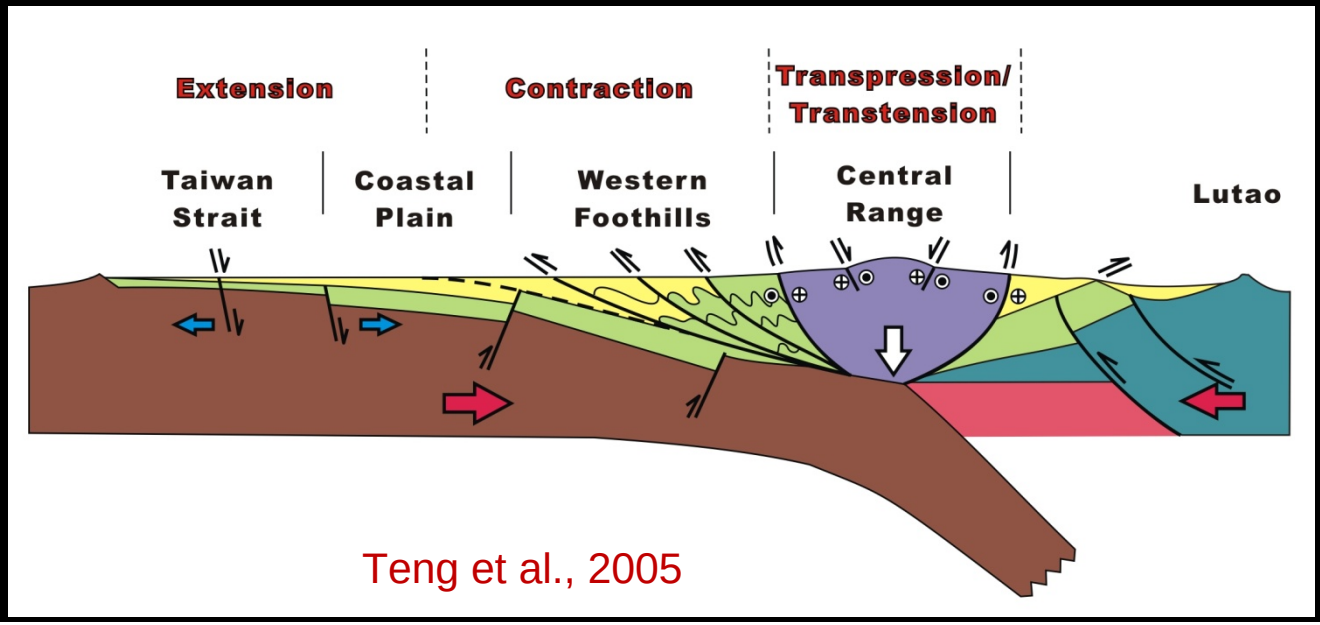
Taiwan Tectonic Model



Kinematic models of Taiwan arc-continent collision

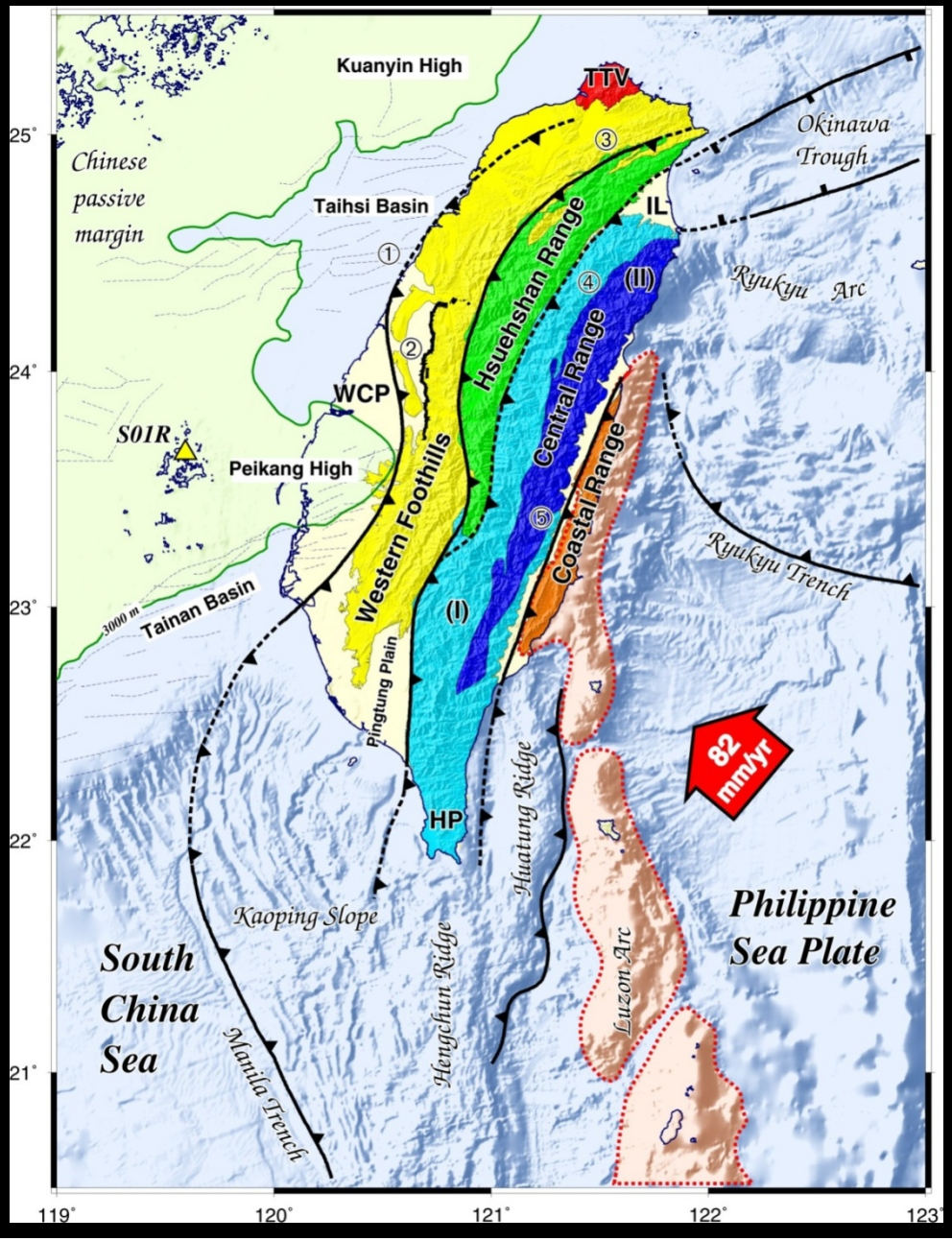


Crespi, 1996



Teng et al., 2005

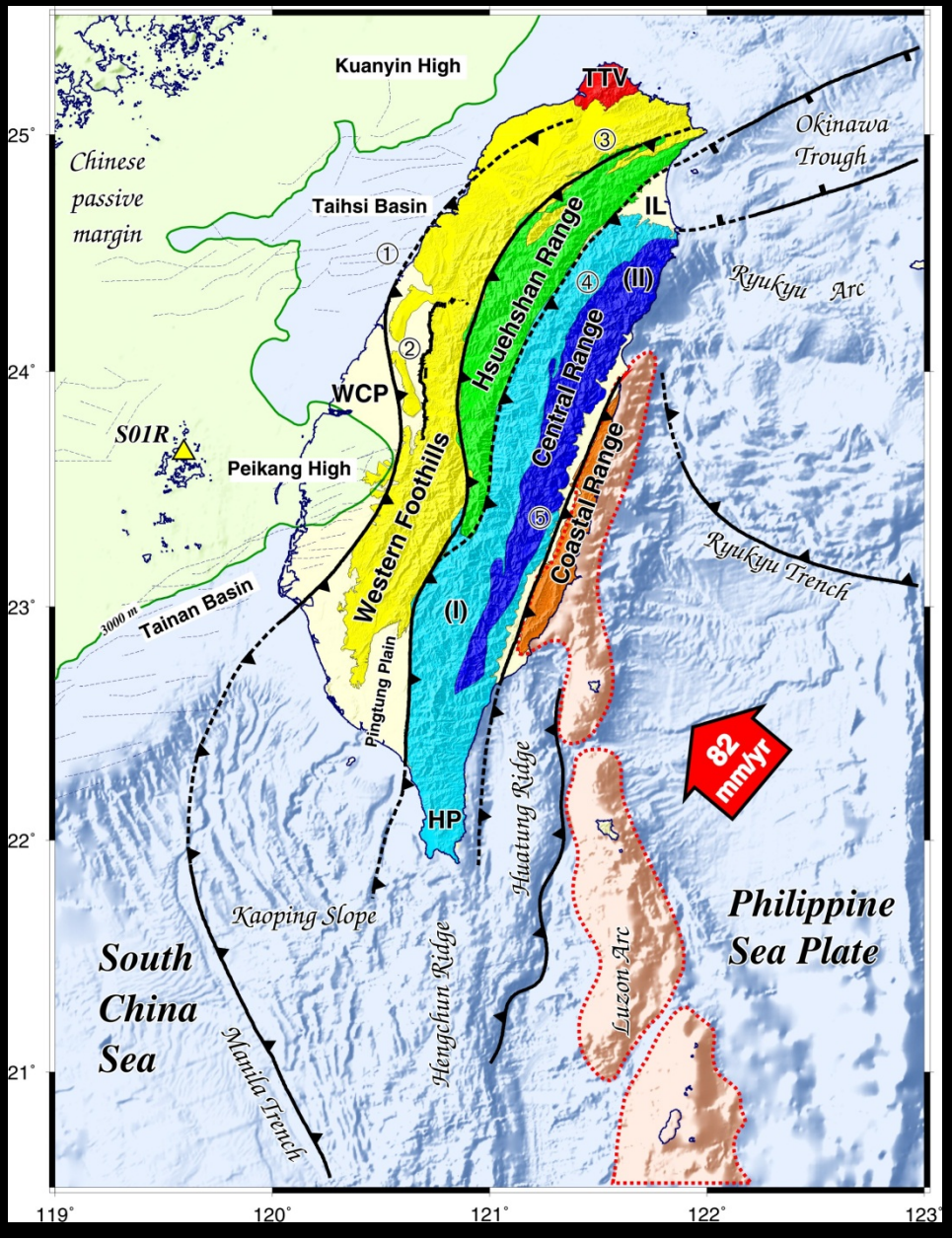
Geology of Taiwan

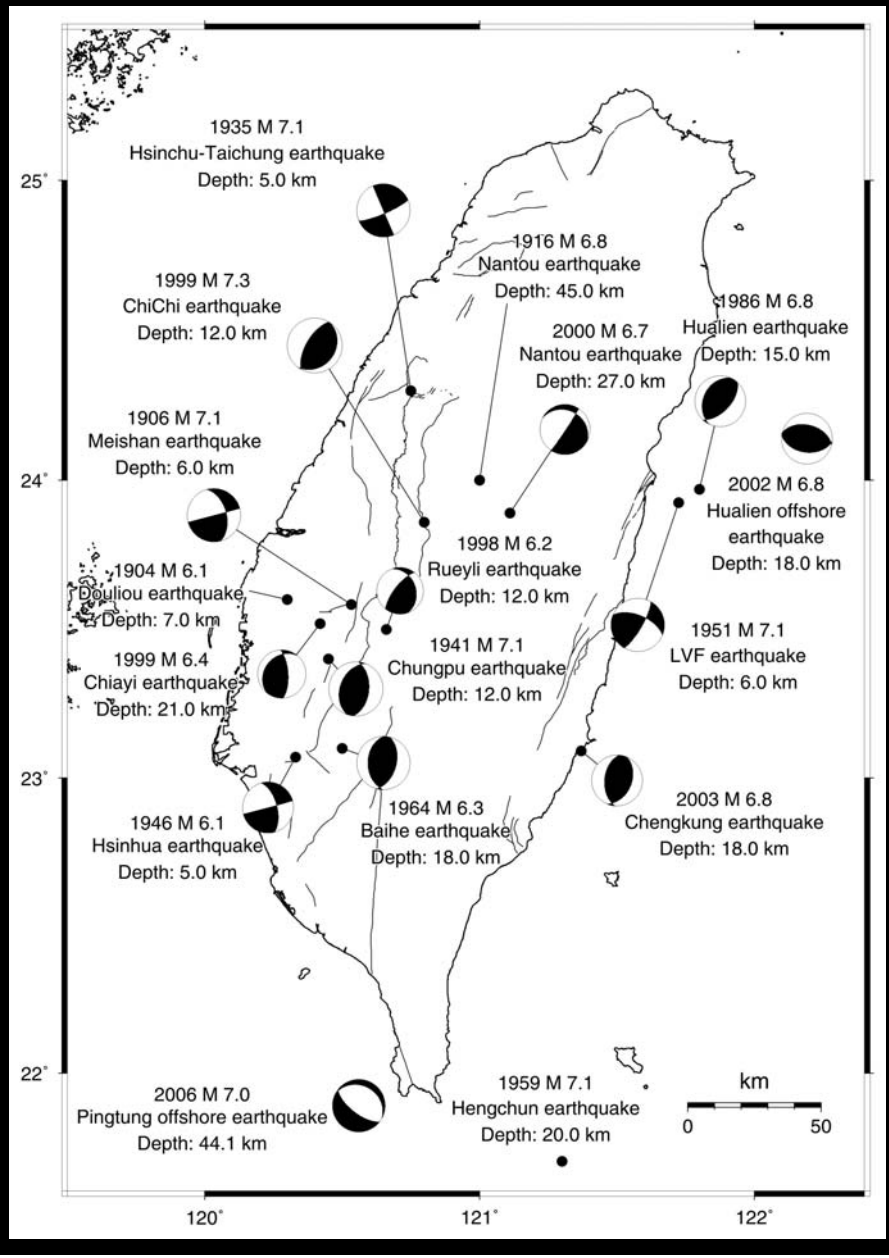


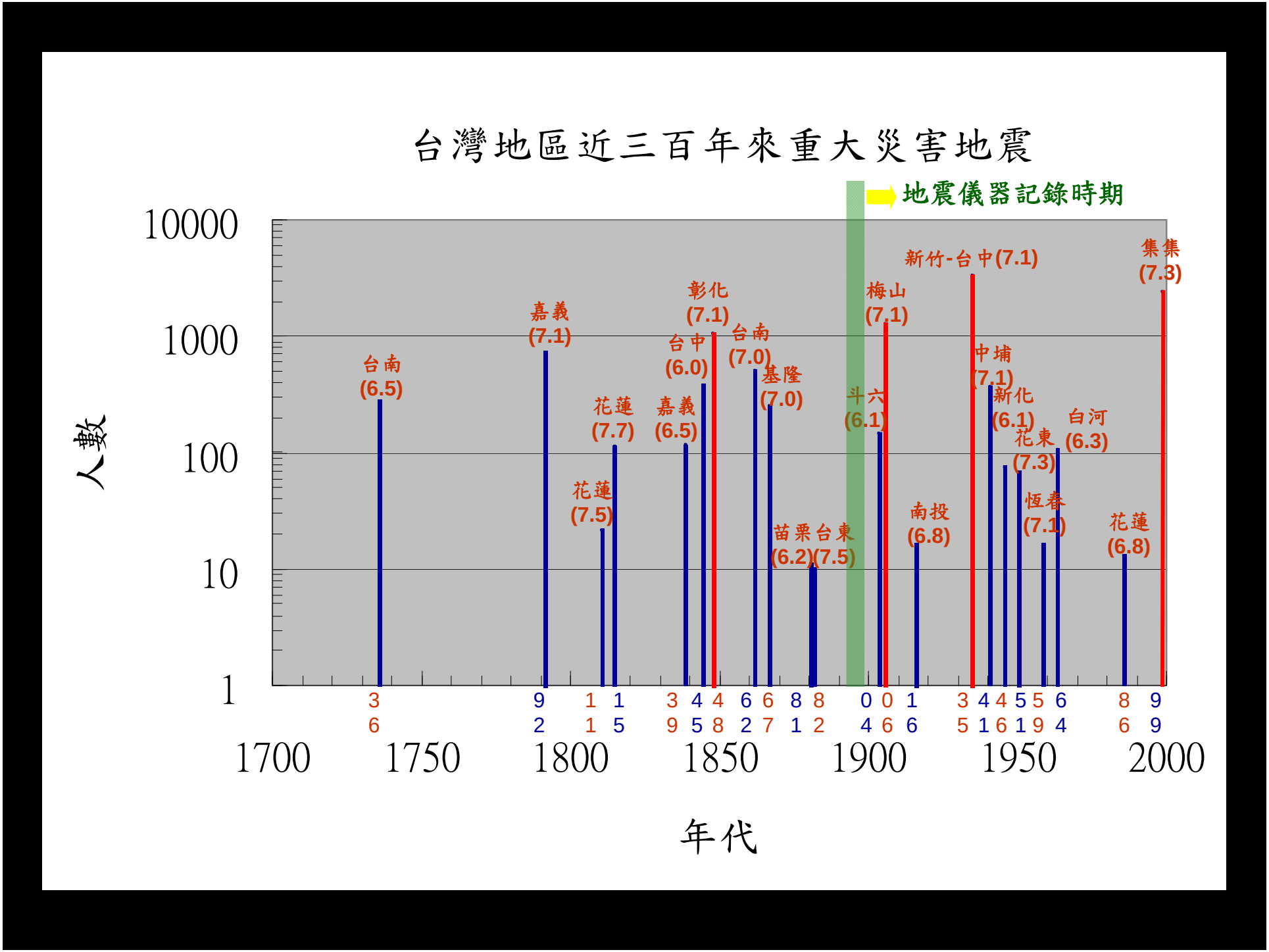
Major seismogenic structures

1. Ryukyu trench system
2. Manila trench system
3. Frontal and out-of sequence thrusts
4. Reactivation of pre-existing structures

Tectonics and large earthquakes in Taiwan






台灣地區近三百年來重大災害地震
地震儀器記錄時期
人數
10000
1000
100
10
1
年代
1700
1750
1800
1850
1900
1950
2000
台南 (6.5)
嘉義 (7.1)
花蓮 (7.7)
花蓮 (7.5)
嘉義 (6.5)
台中 (6.0)
彰化 (7.1)
台南 (7.0)
基隆 (7.0)
苗栗台東 (6.2)(7.5)
斗六 (6.1)
梅山 (7.1)
南投 (6.8)
新竹-台中(7.1)
中埔 (7.1)
新化 (6.1)
花東 (7.3)
恆春 (7.1)
白河 (6.3)
花蓮 (6.8)
集集 (7.3)
36 92 11 15 39 45 48 62 67 81 82 04 06 16 35 41 61 95 19 64 86 99

Taiwan Geodetic Network

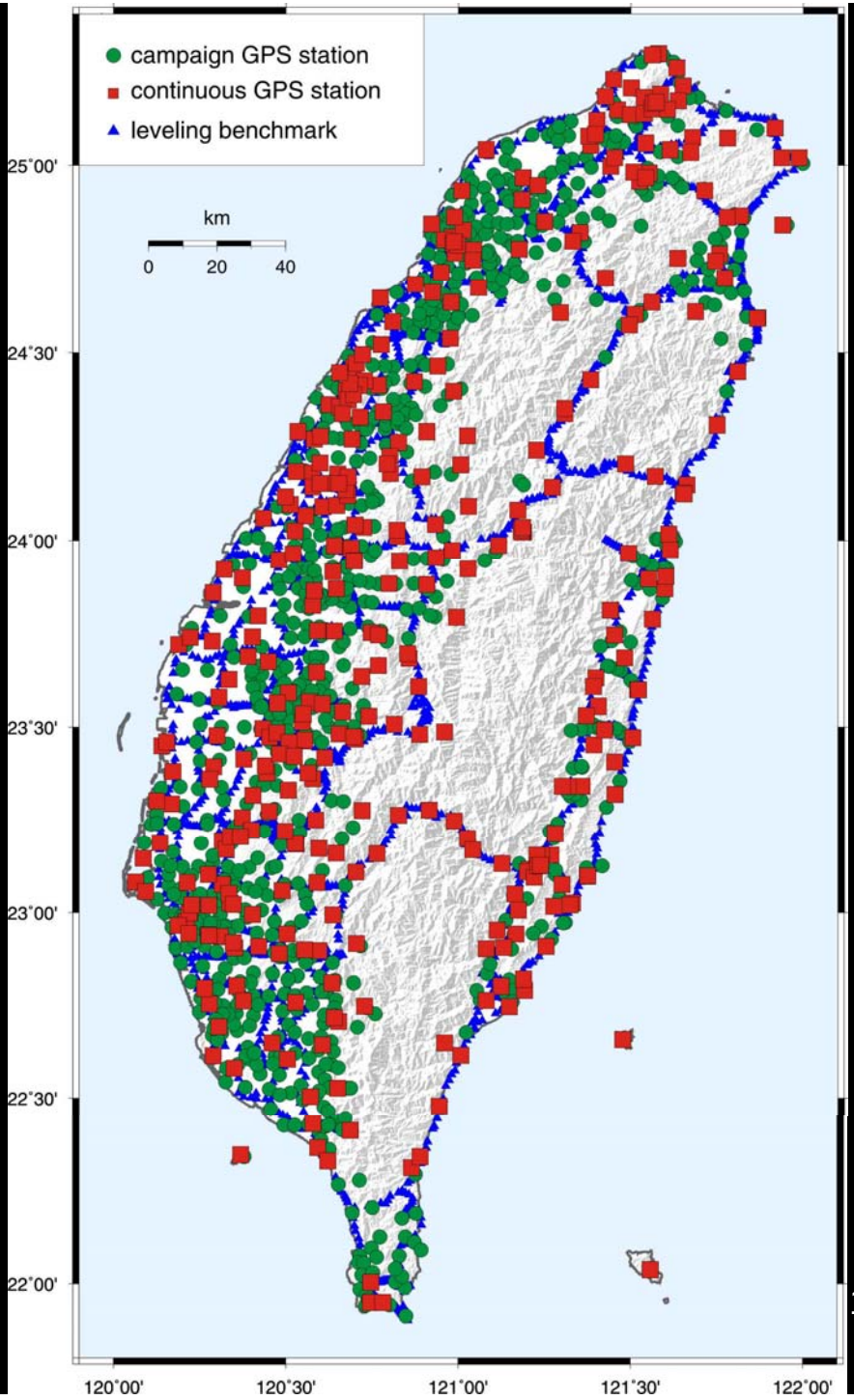
~400 continuous GPS stations

~1000 campaign GPS stations

Precise leveling measurements

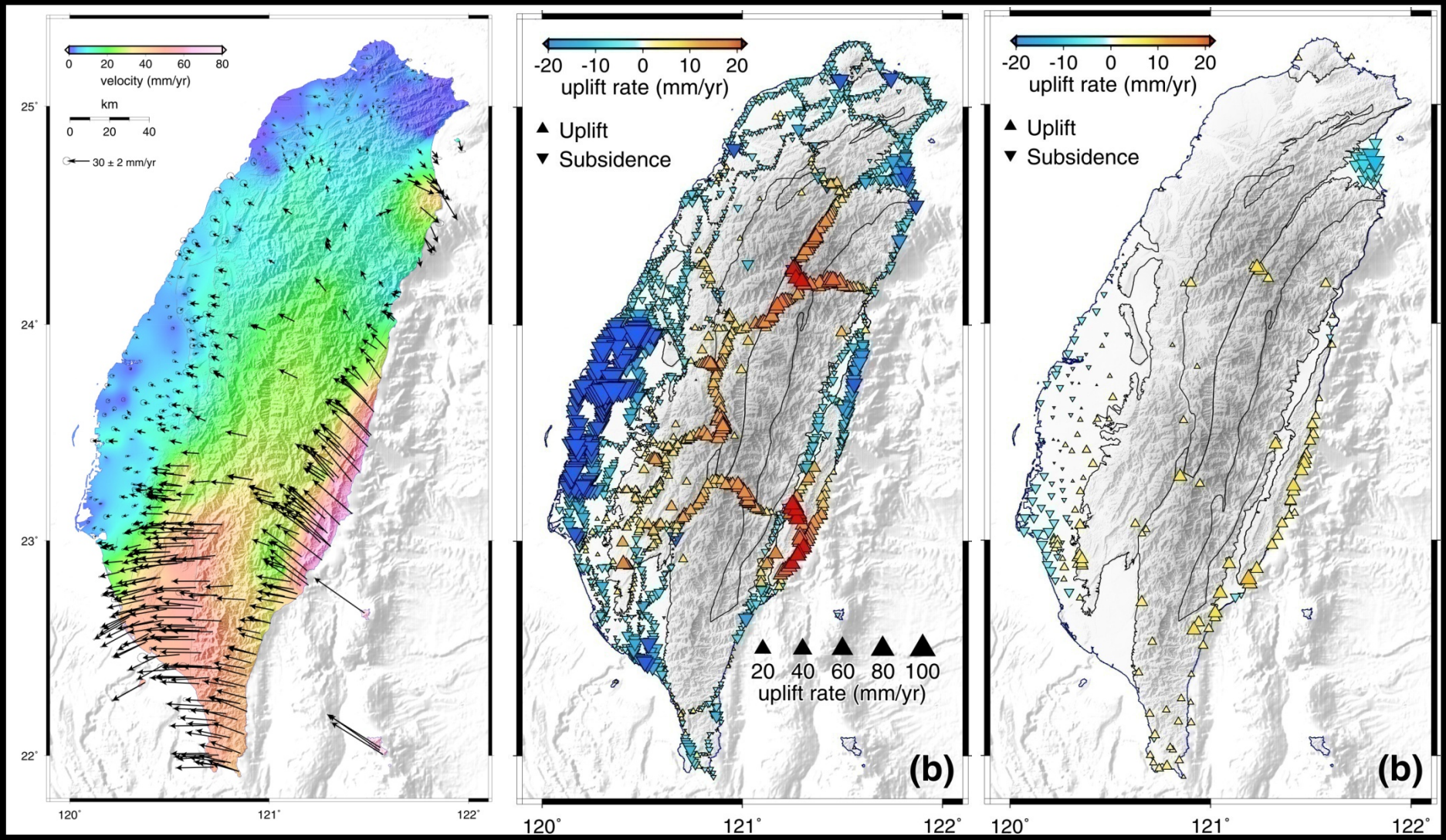
* Dense near-fault observations

* Lack of stations in the hinterland and off-shore

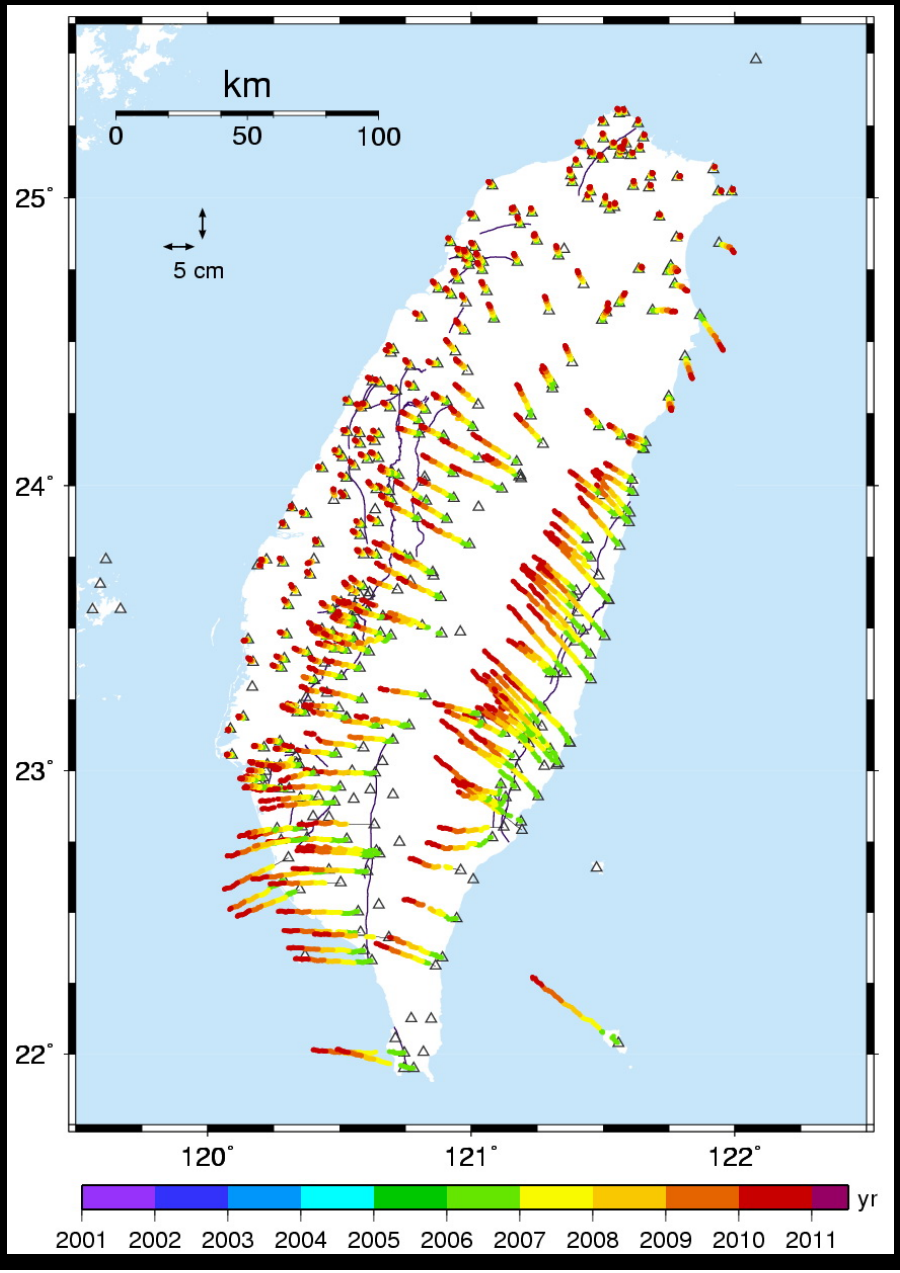


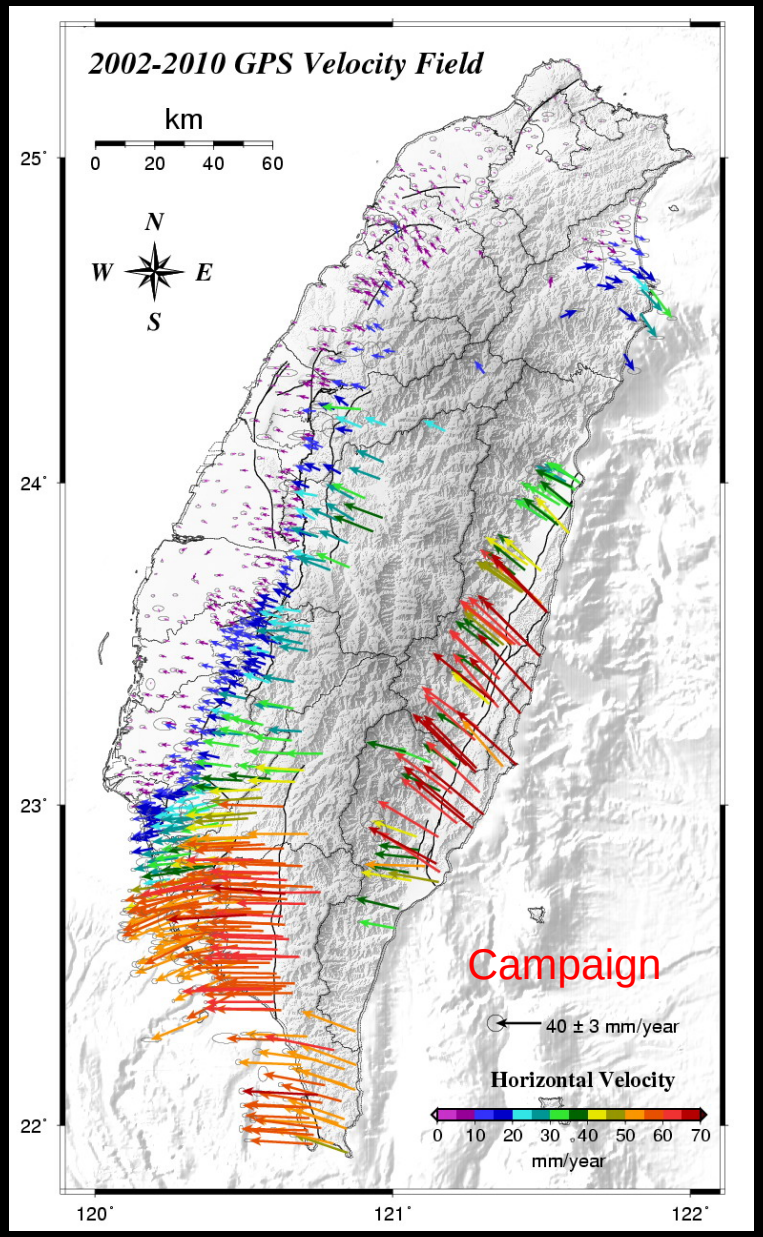
Taiwan Velocity Field

GPS Horizontal Velocities **Short-term Vertical Velocities** **Long-term Vertical Velocities**

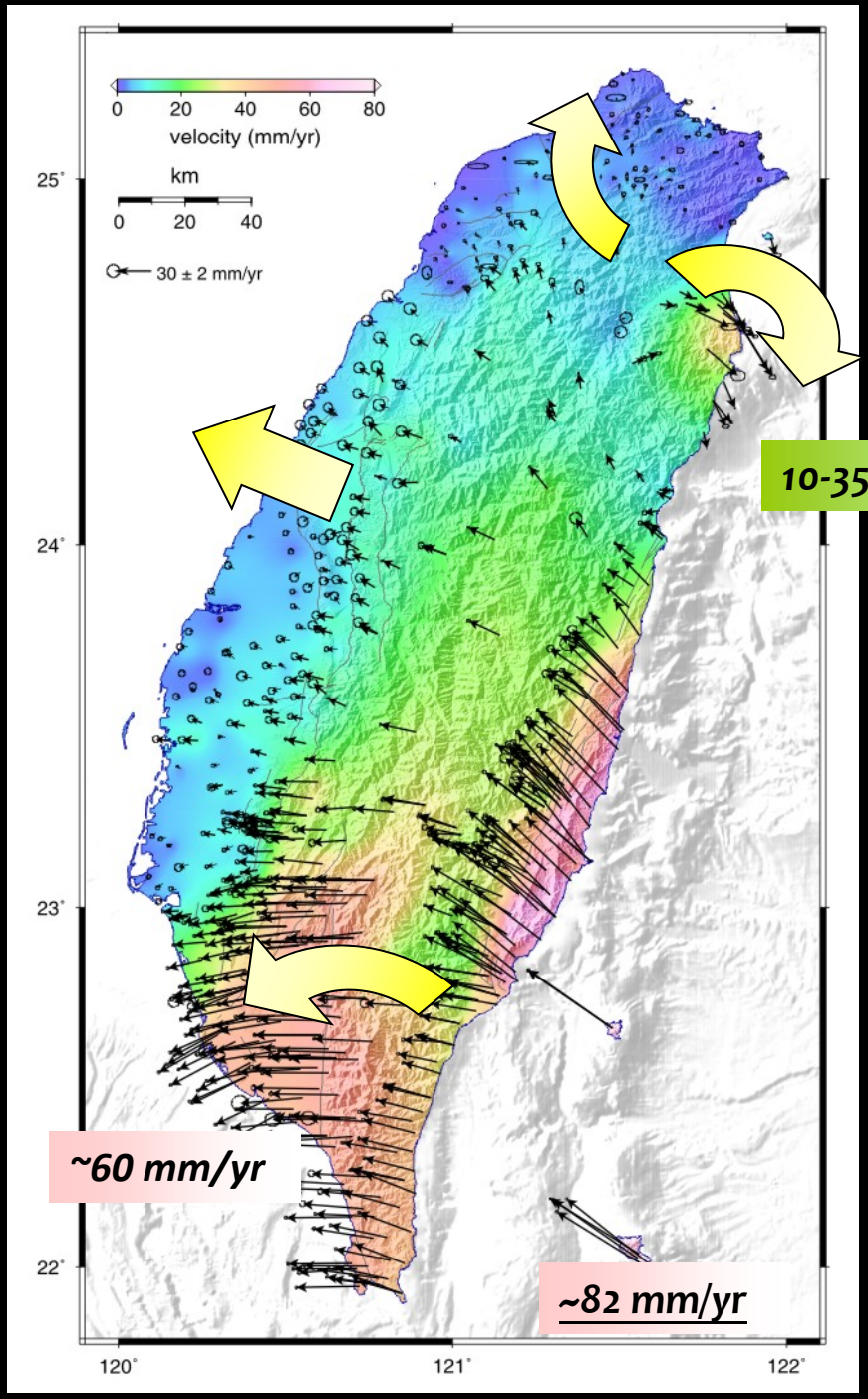


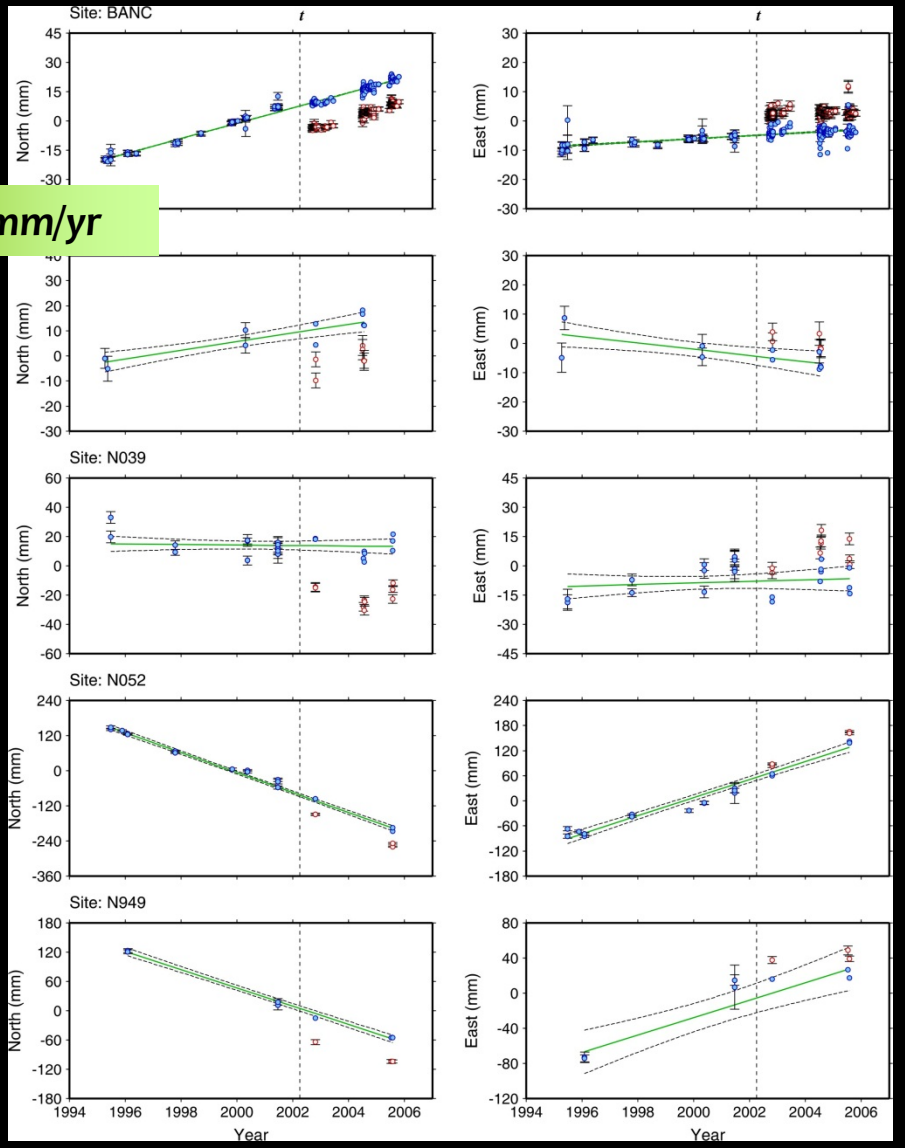
GPS velocity field





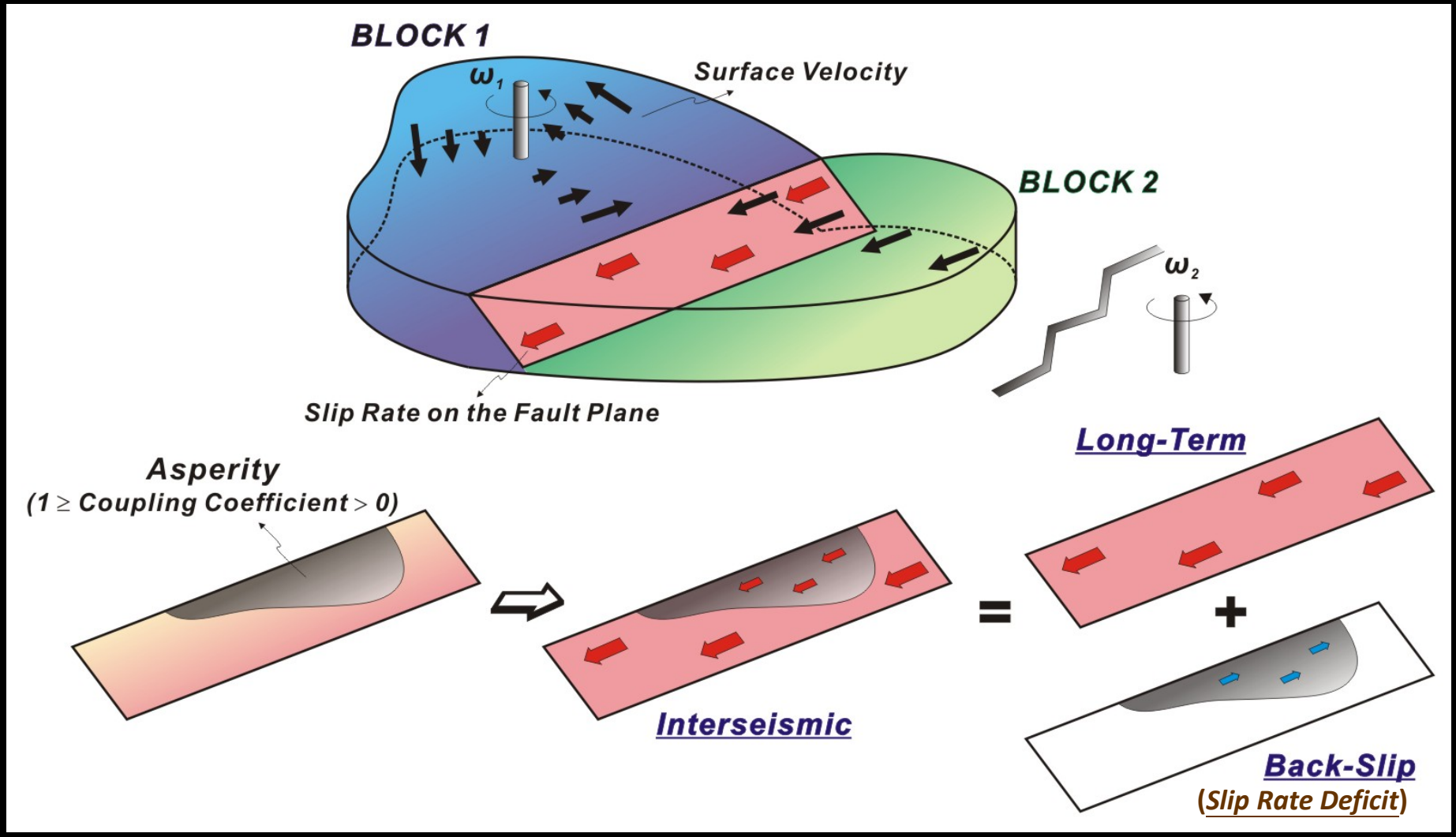
GPS Velocity Field in Taiwan



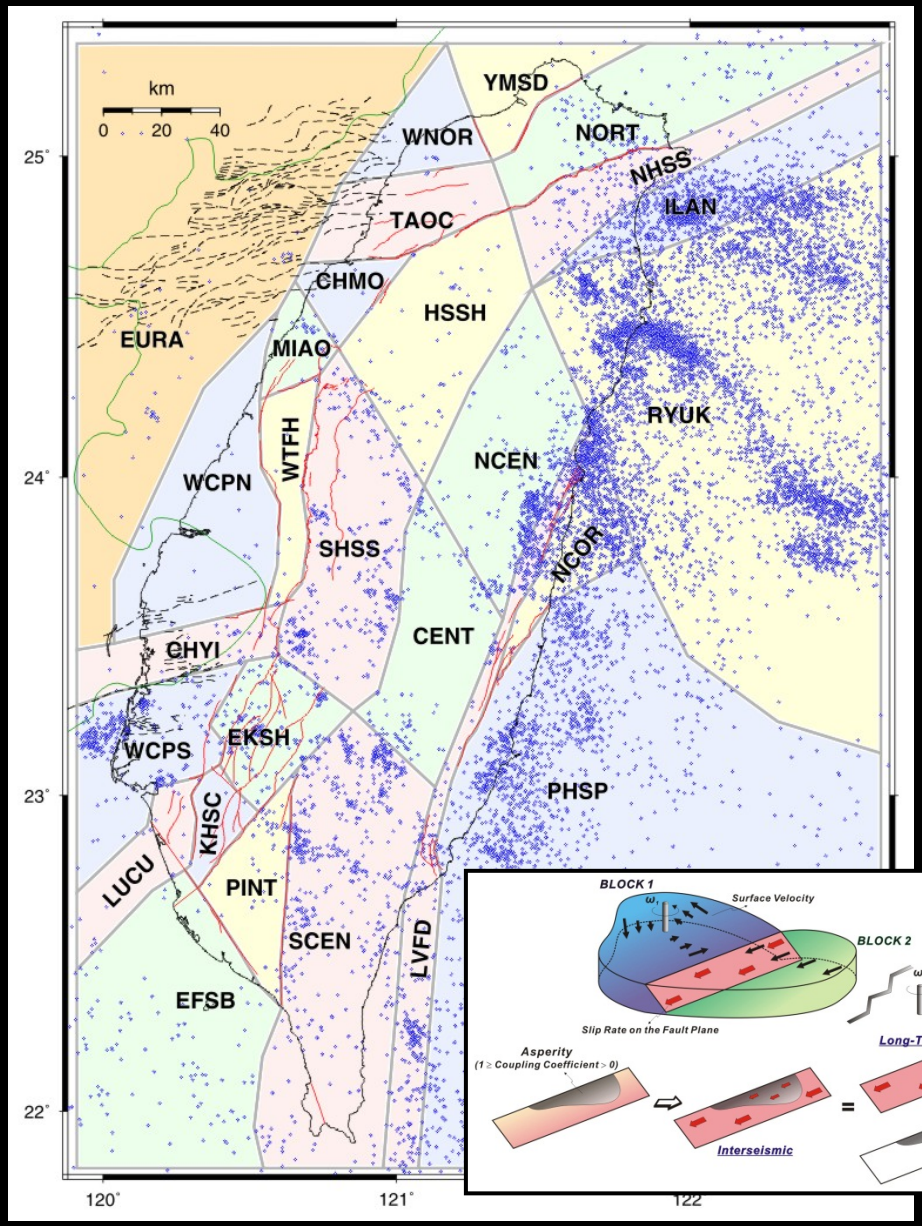


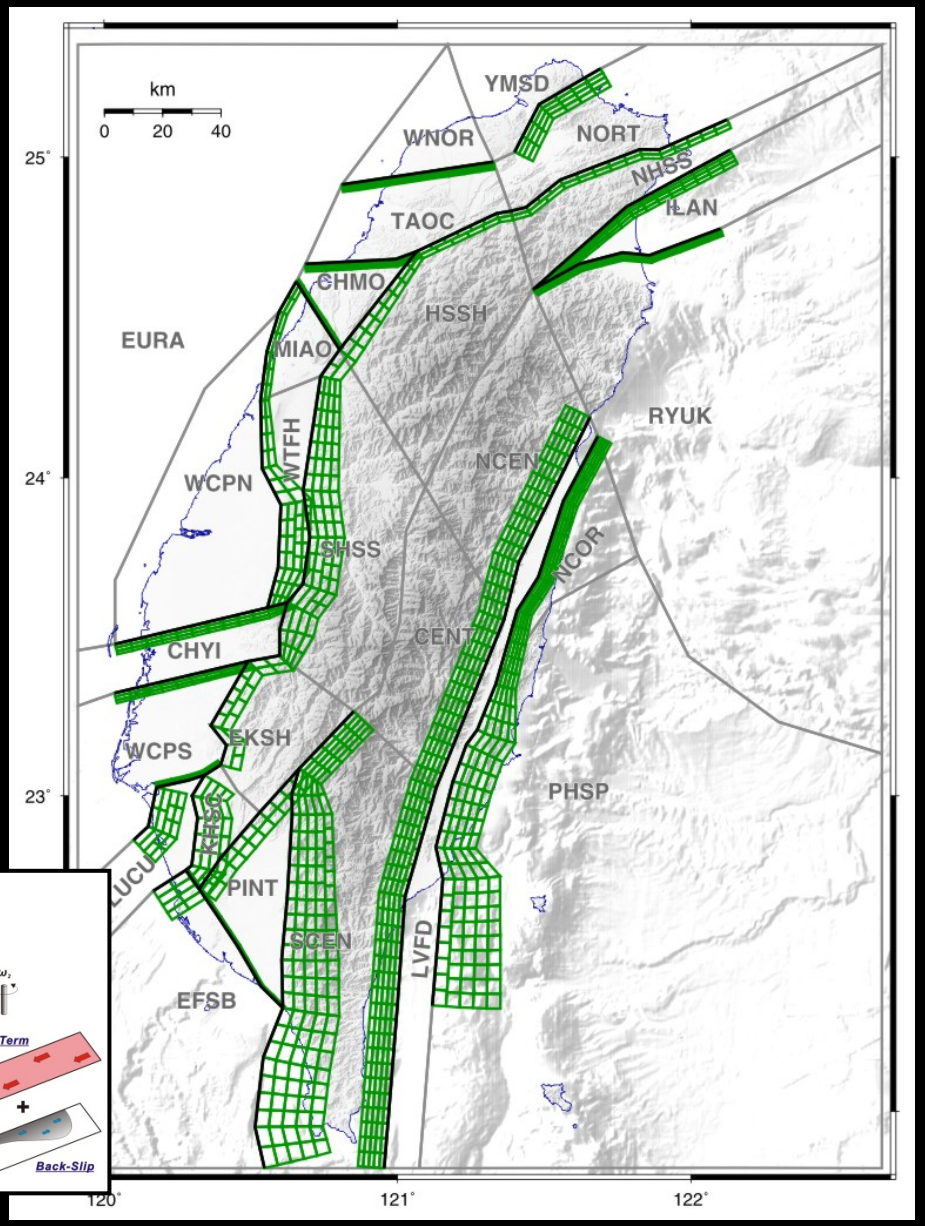
3D Block Modeling Approach (Horizontal Data)

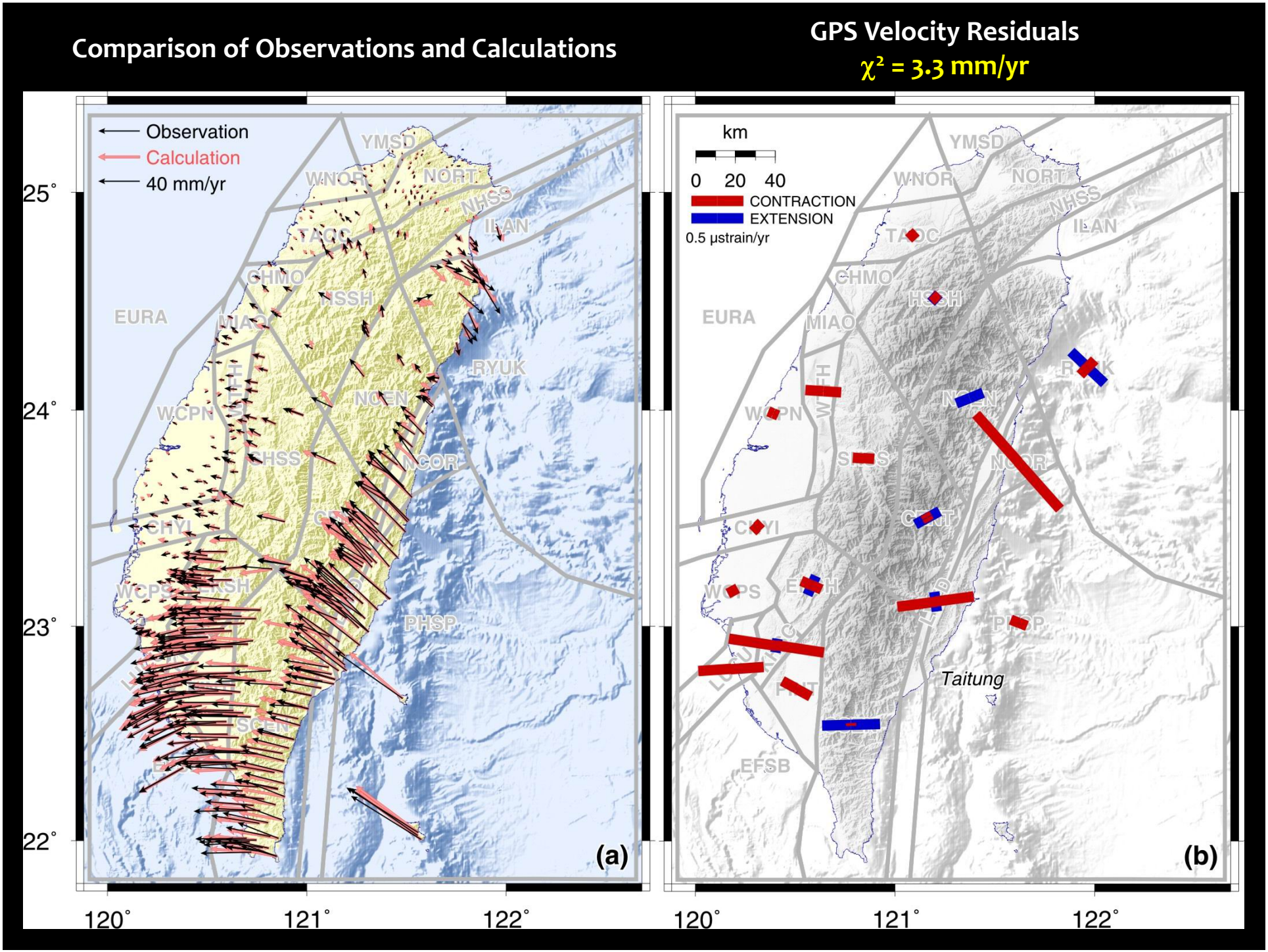
Concept of modeling interseismic velocity field (DENODE: *McCaffrey*, 2002)

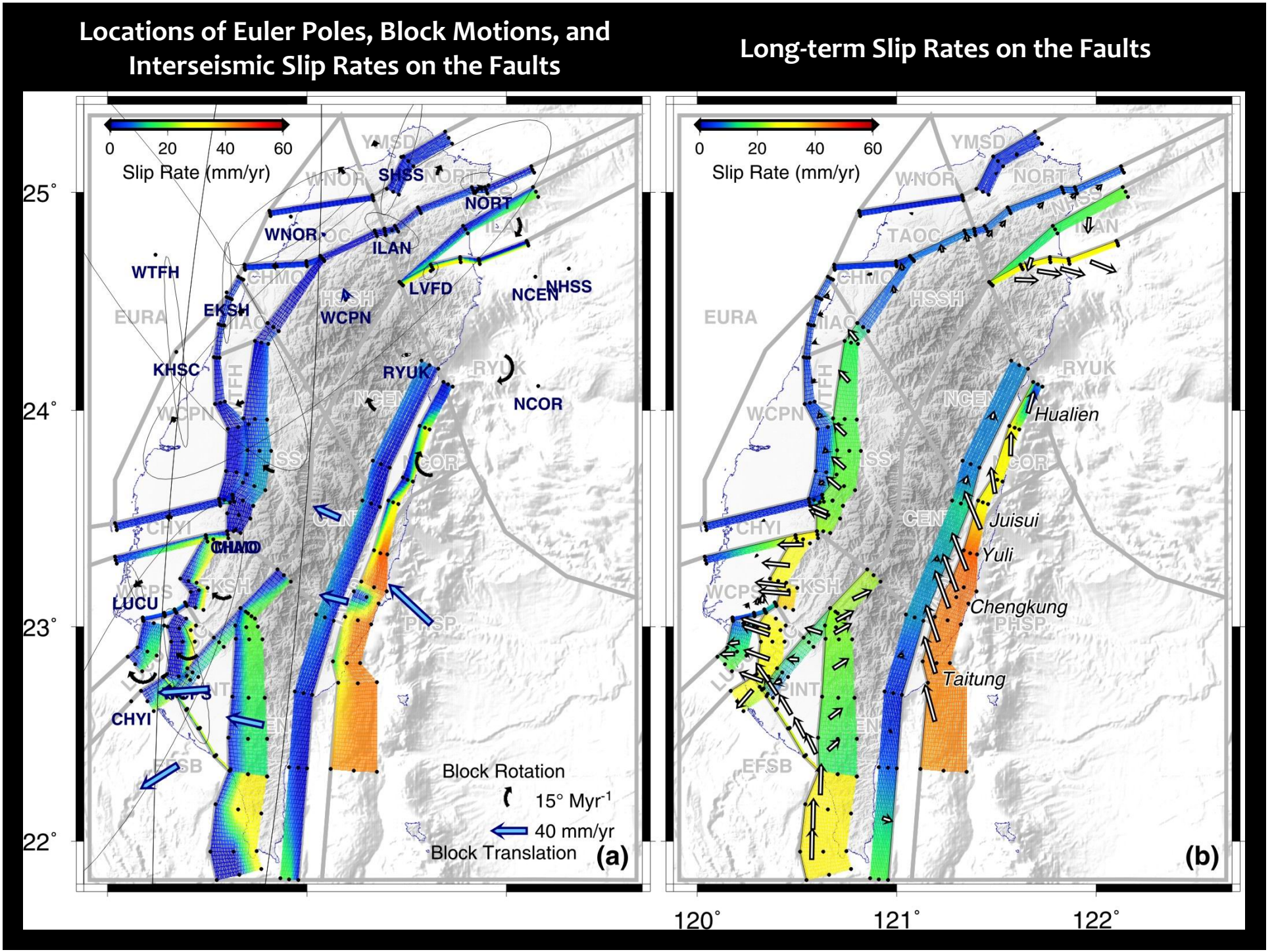


Tectonic Block and Fault Configurations

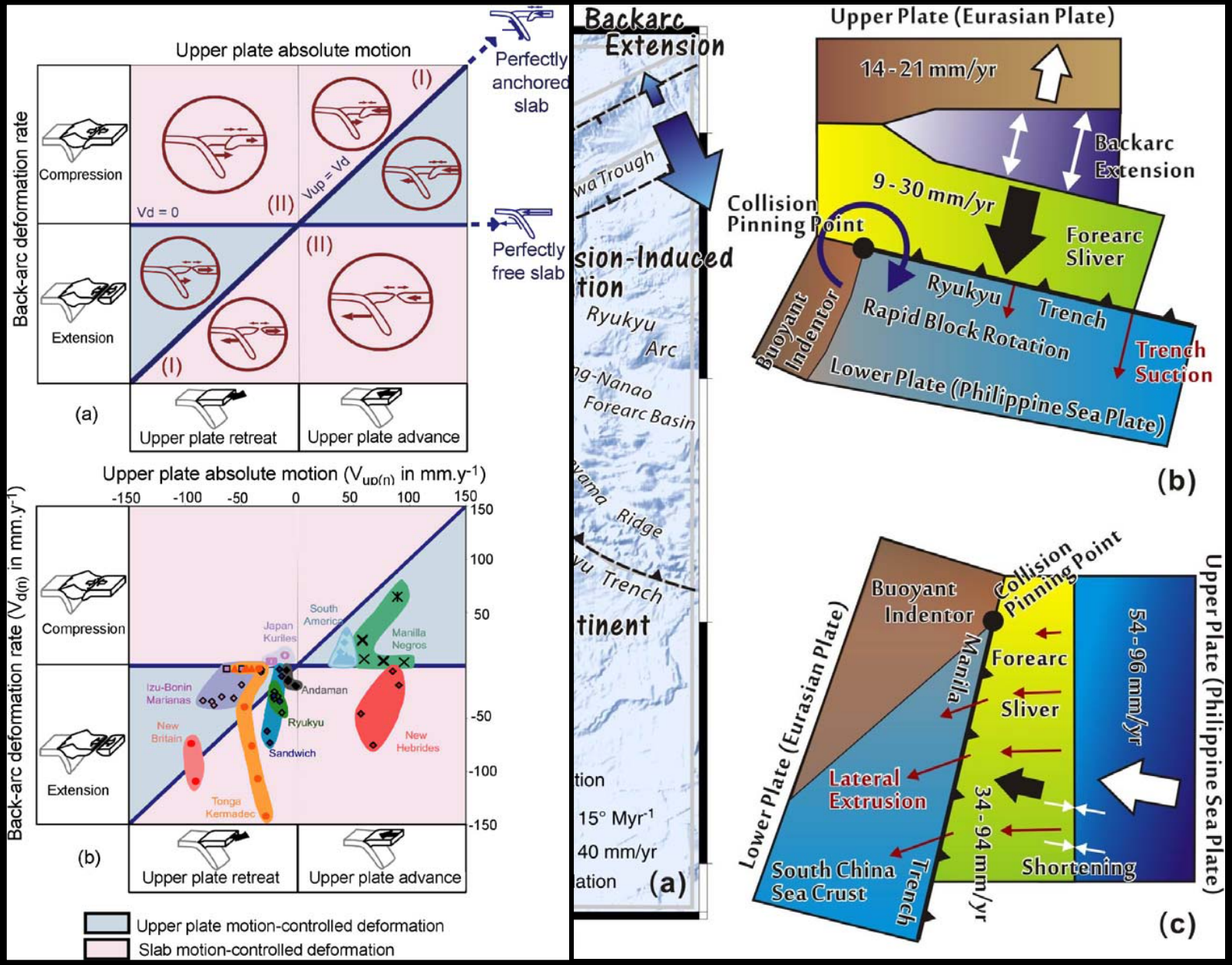





Comparison of Observations and Calculations
GPS Velocity Residuals
χ² = 3.3 mm/yr
Observation
Calculation
40 mm/yr
km
0 20 40
CONTRACTION
EXTENSION
0.5 μstrain/yr
YMSD
WNOR
NORT
NHSS
ILAN
TAOC
CHMO
HSSH
EURA
MIAO
RYUK
NCEN
WCPN
NCOR
CHYI
WCPS
PHSP
ESCN
EFSB
Taitung
25°
24°
23°
22°
120°
121°
122°
(a)
(b)

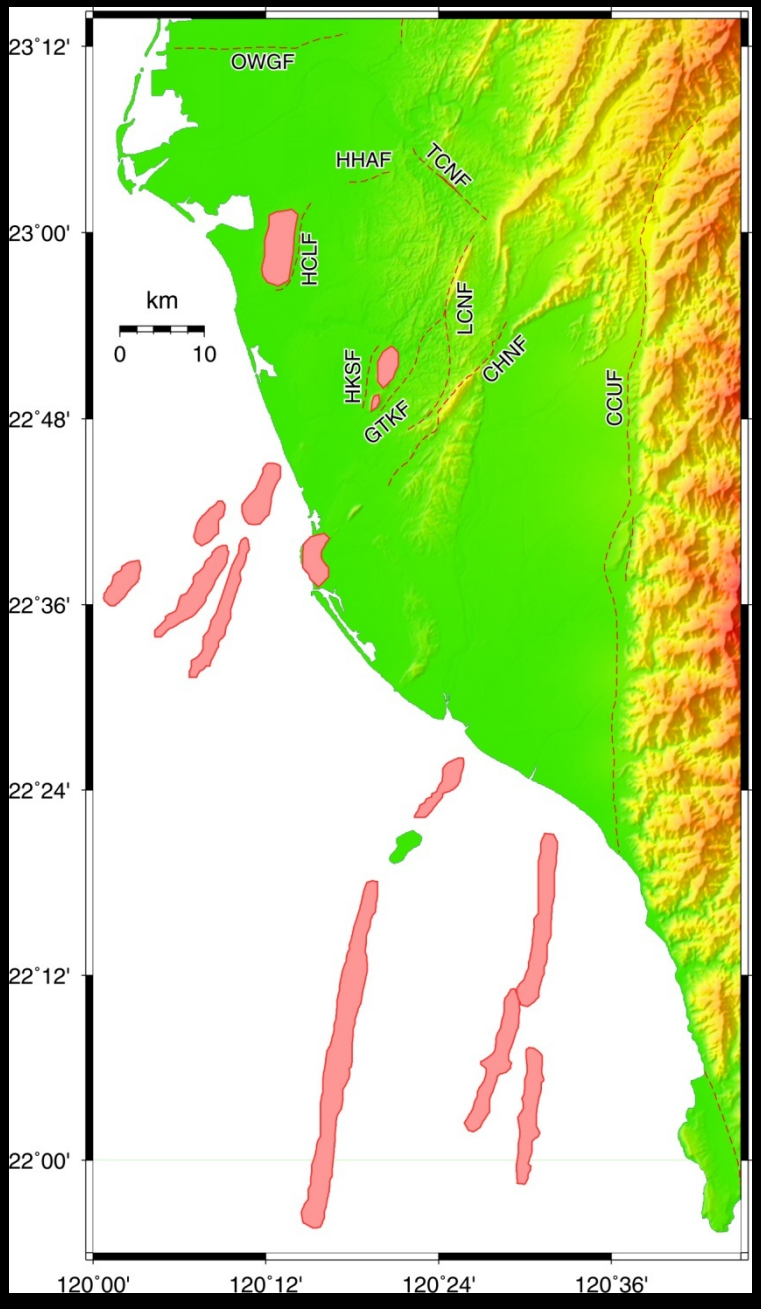

Locations of Euler Poles, Block Motions, and Interseismic Slip Rates on the Faults
Long-term Slip Rates on the Faults
0 20 40 60
Slip Rate (mm/yr)
SHSS
NORT
WNOR
ILAN
WTFH
LVFD
NCEN
NHSS
EKSH
WCPN
KHSC
RYUK
NCOR
CHAO
LUCU
CHYI
PHSP
Block Rotation
15° Myr-1
40 mm/yr
Block Translation
(a)
Hualien
Juisui
Yuli
Chengkung
Taitung
(b)
25°
24°
23°
22°
120°
121°
122°

Modern Tectonic Model of Taiwan



Heuret and Lallemand [2005]

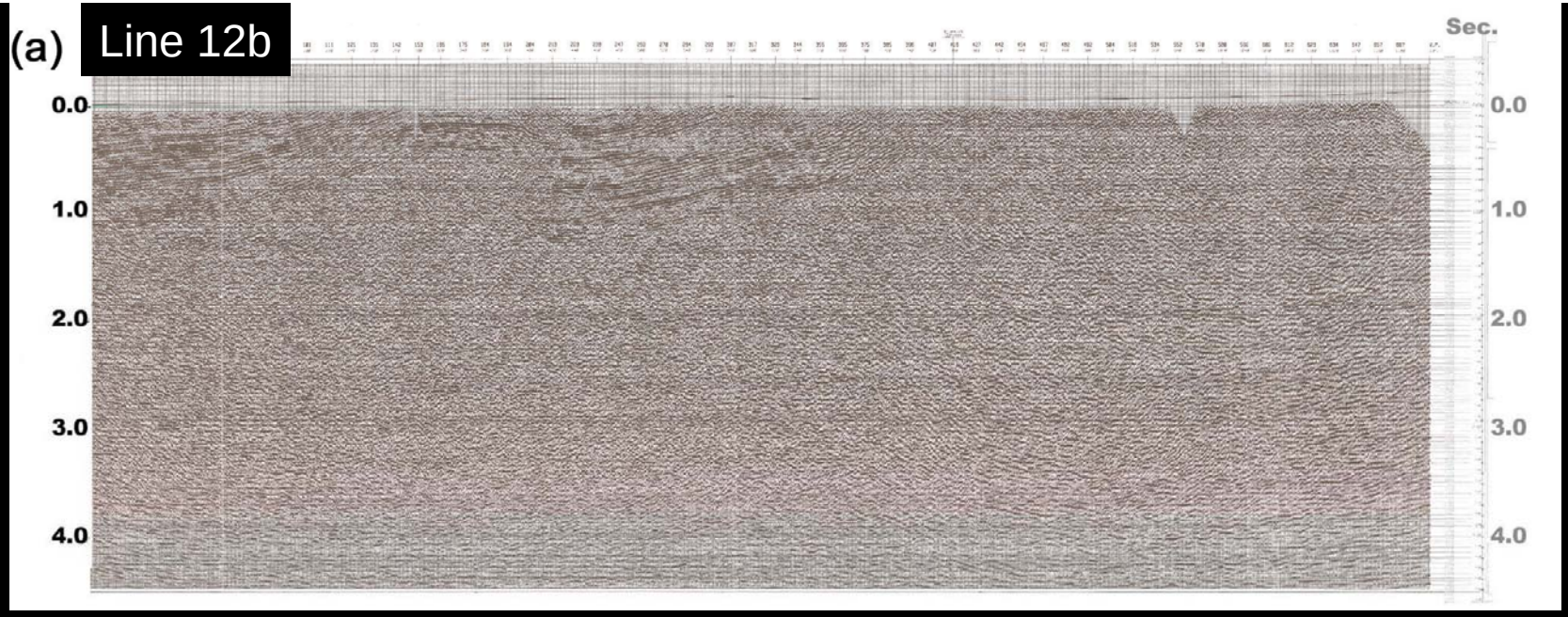
Distribution of mud diapirs in SW Taiwan



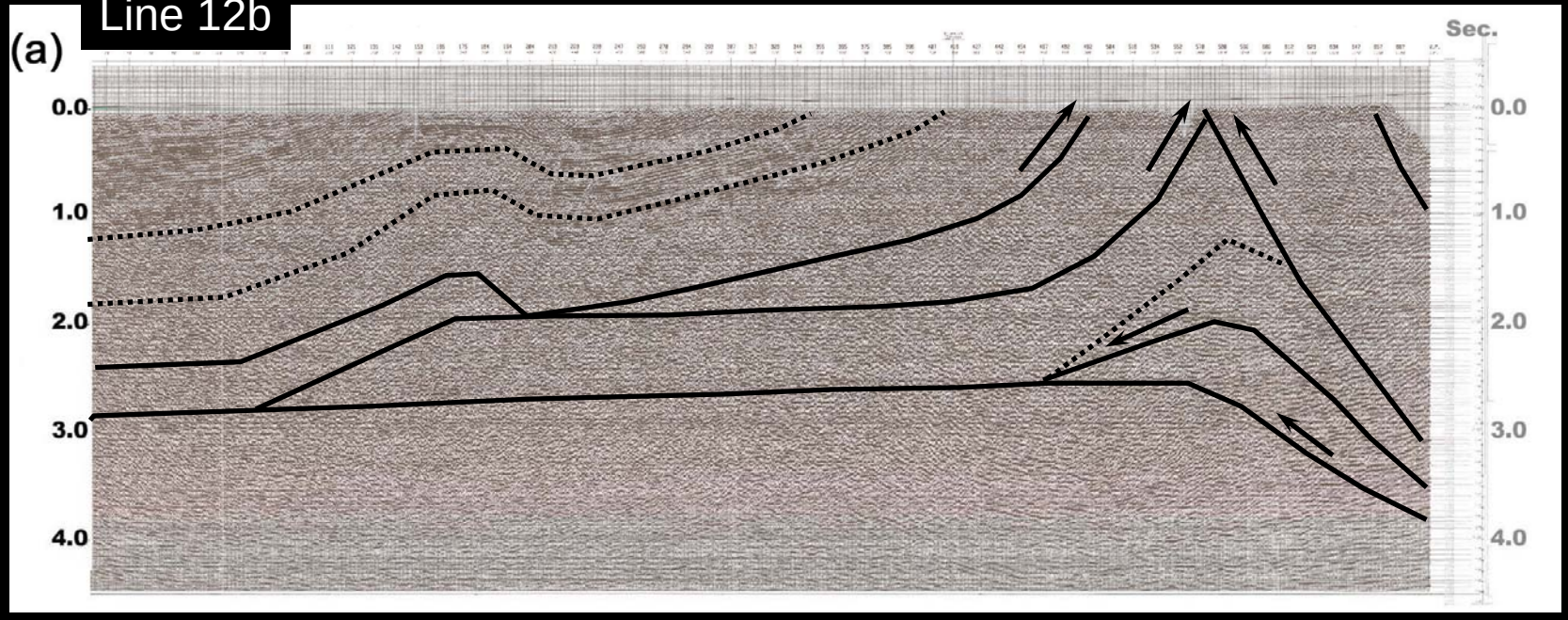
- Generated offshore
- Stop being active onshore
- Appearing inland caused by uplift and erosion

Reactivation of inland mud diapir in the present-day crustal deformation remains unclear.

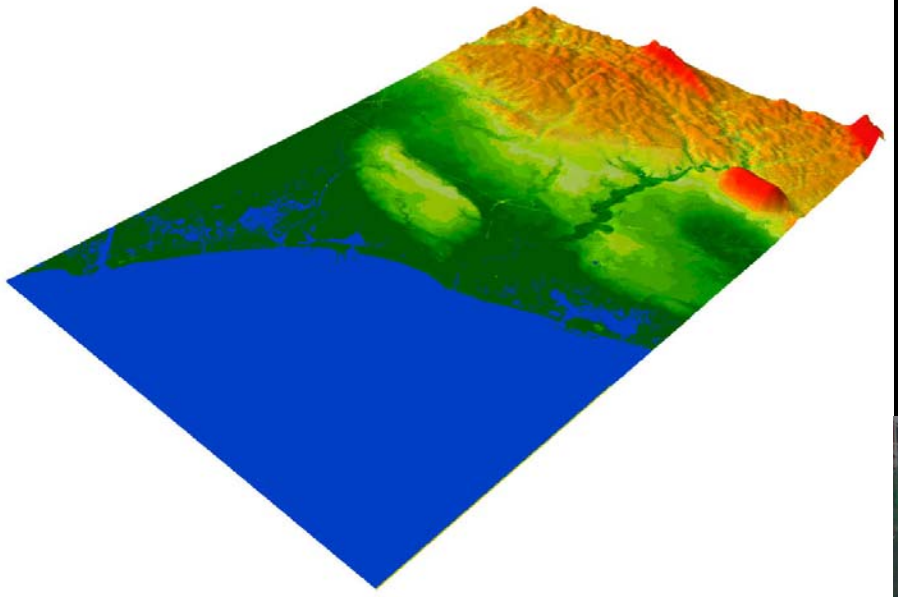
(a) Line 12b



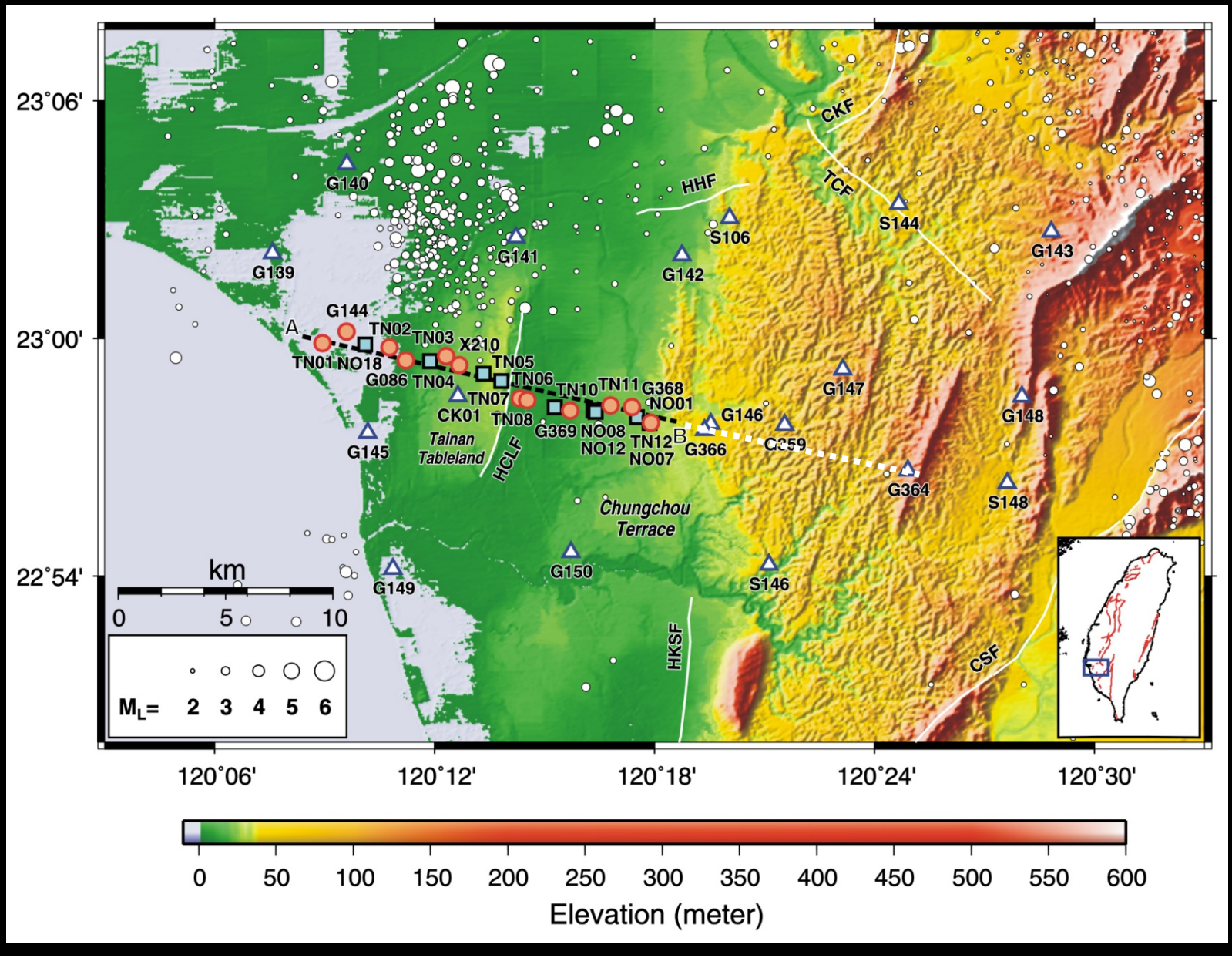
(a) Line 12b

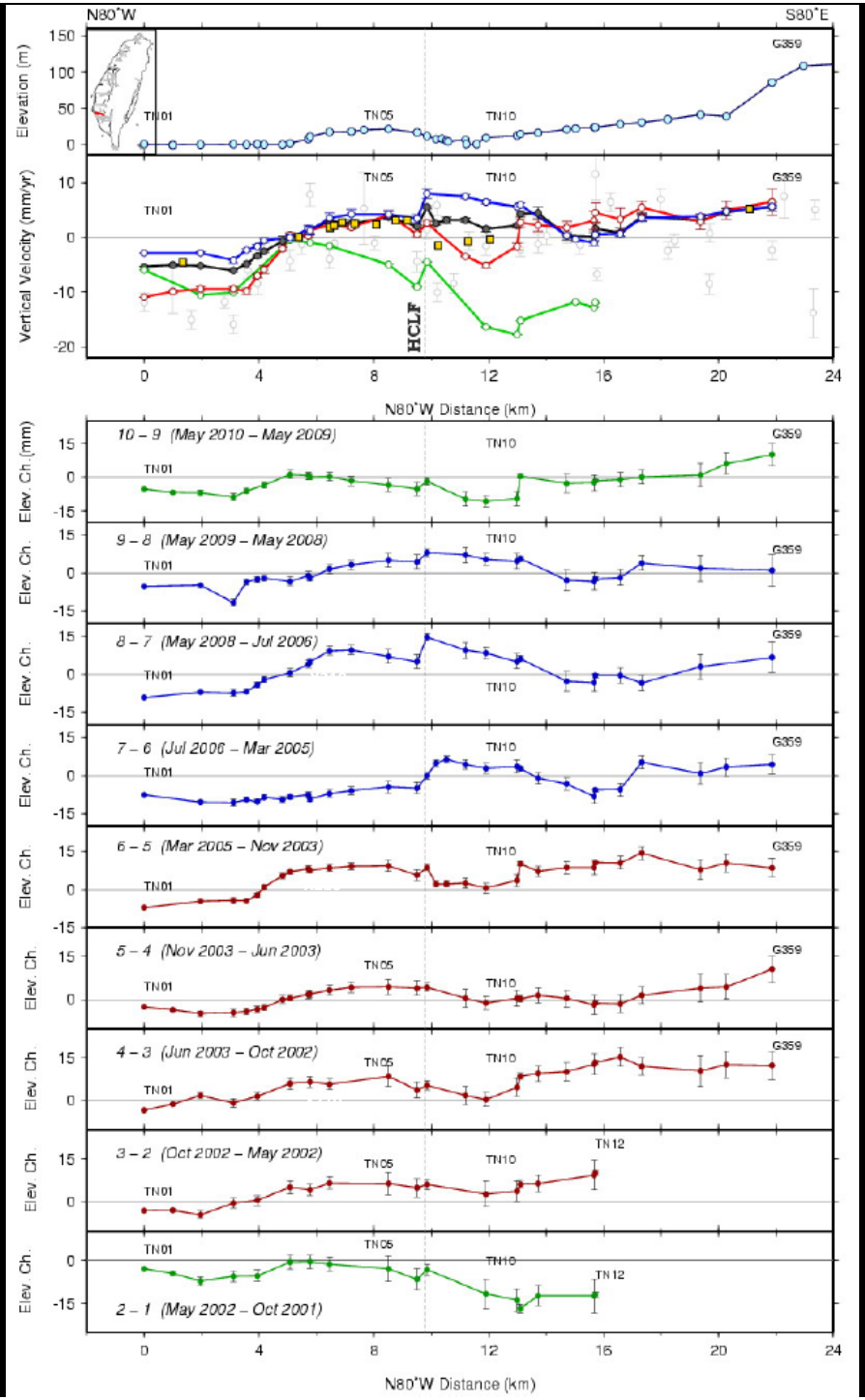


Episodic fault creep in the Tainan tableland

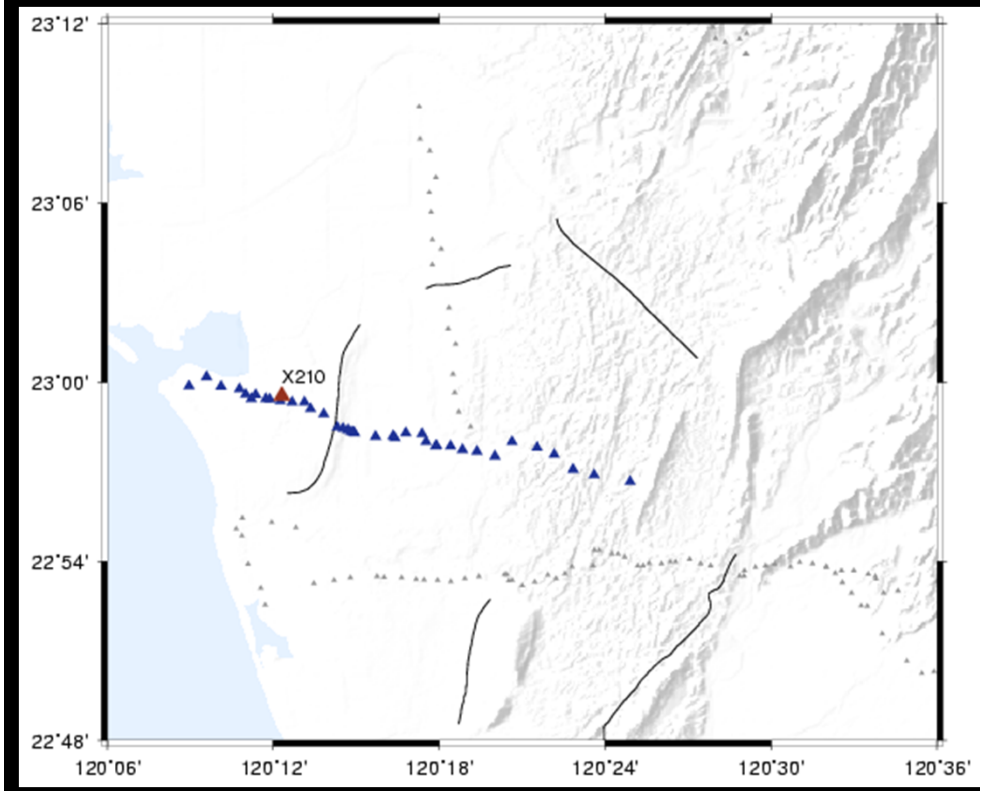


GPS and precise leveling network in Tainan

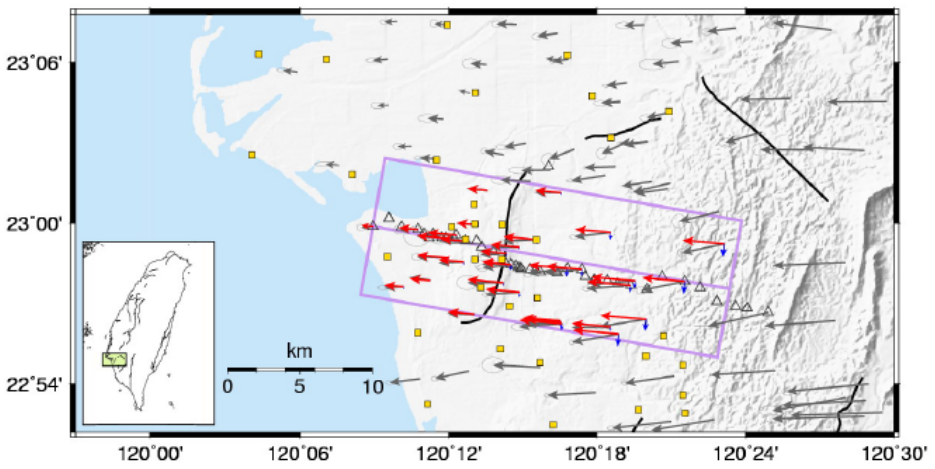


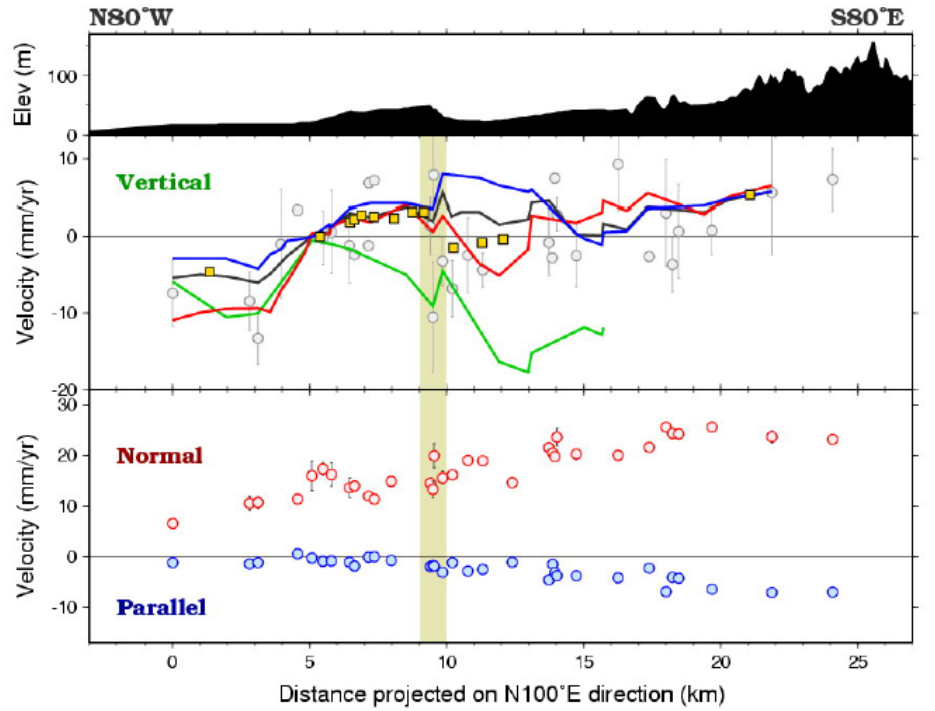


Precise leveling in Tainan



Hypothetical models for the Tainan vertical motion

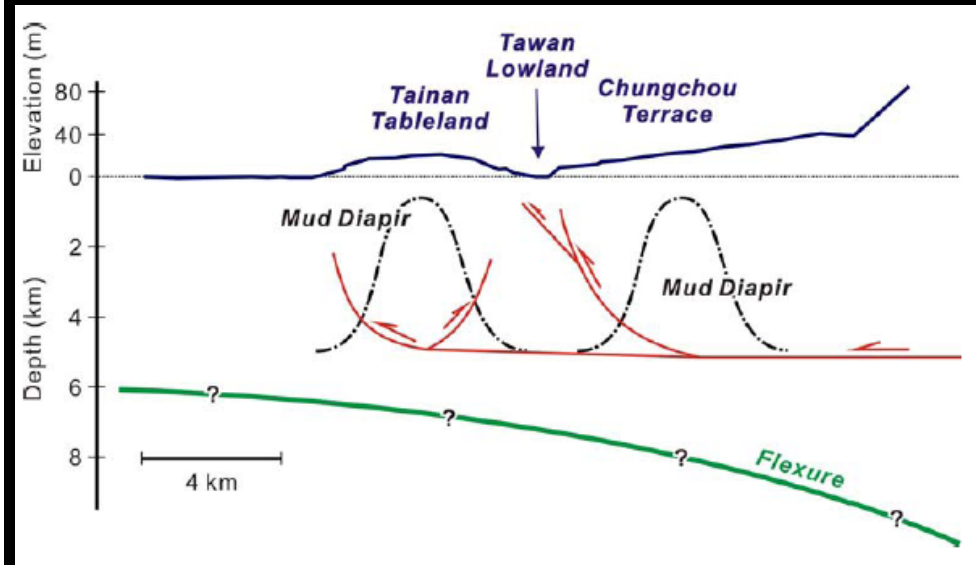




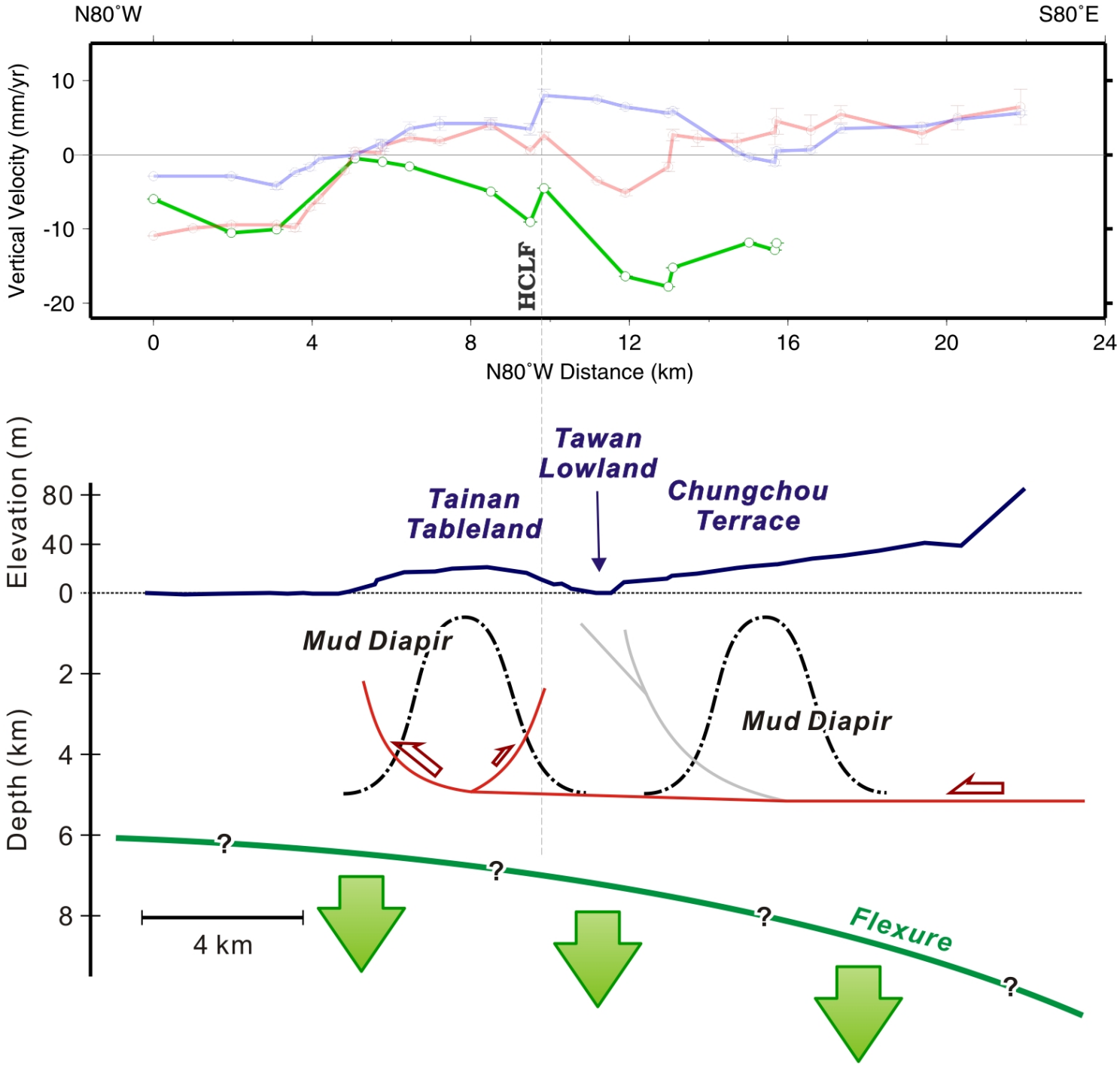
（1）Subsidence of the foreland basin

（2）Development of mud diapir

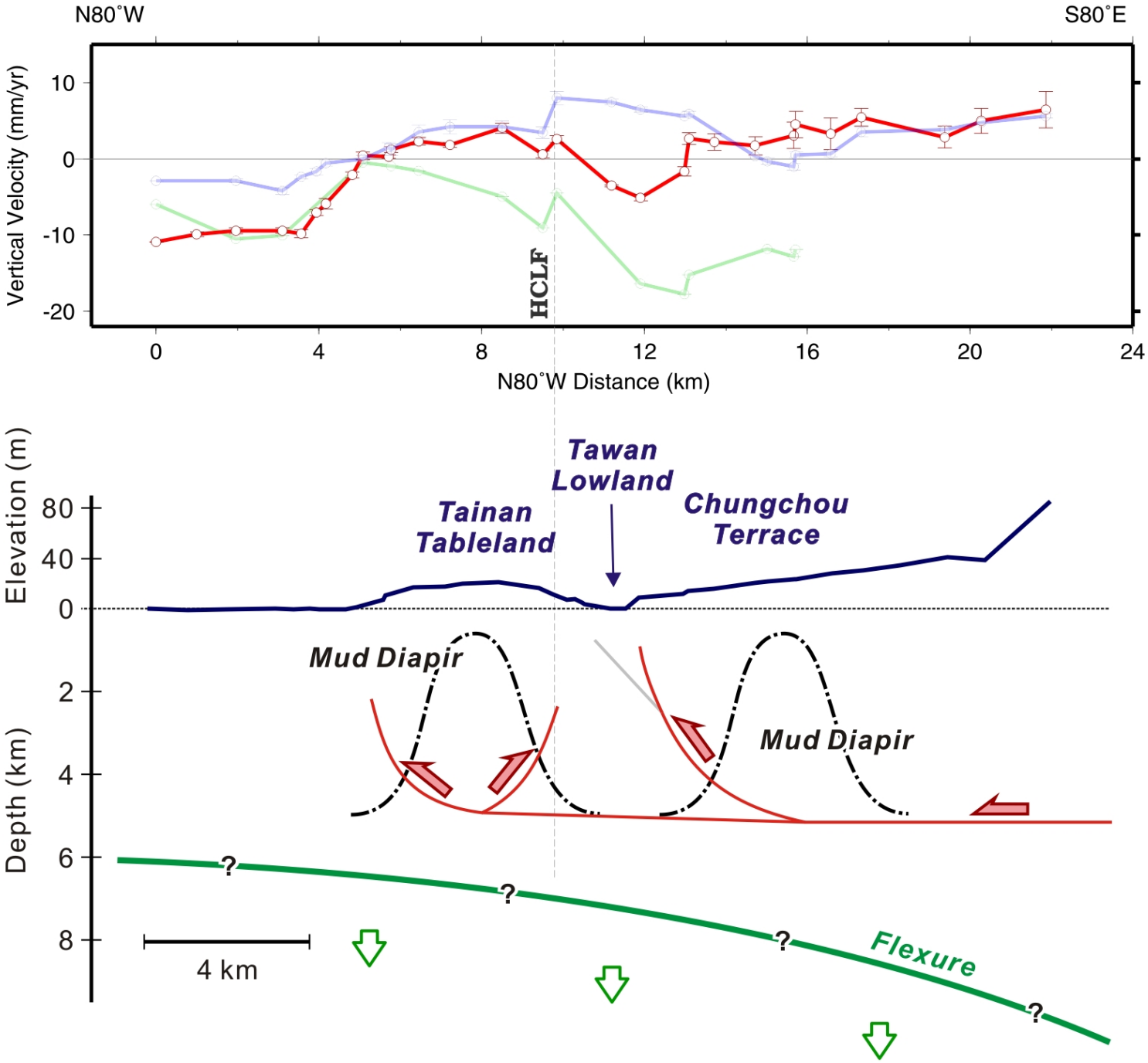
（3）Fault motion



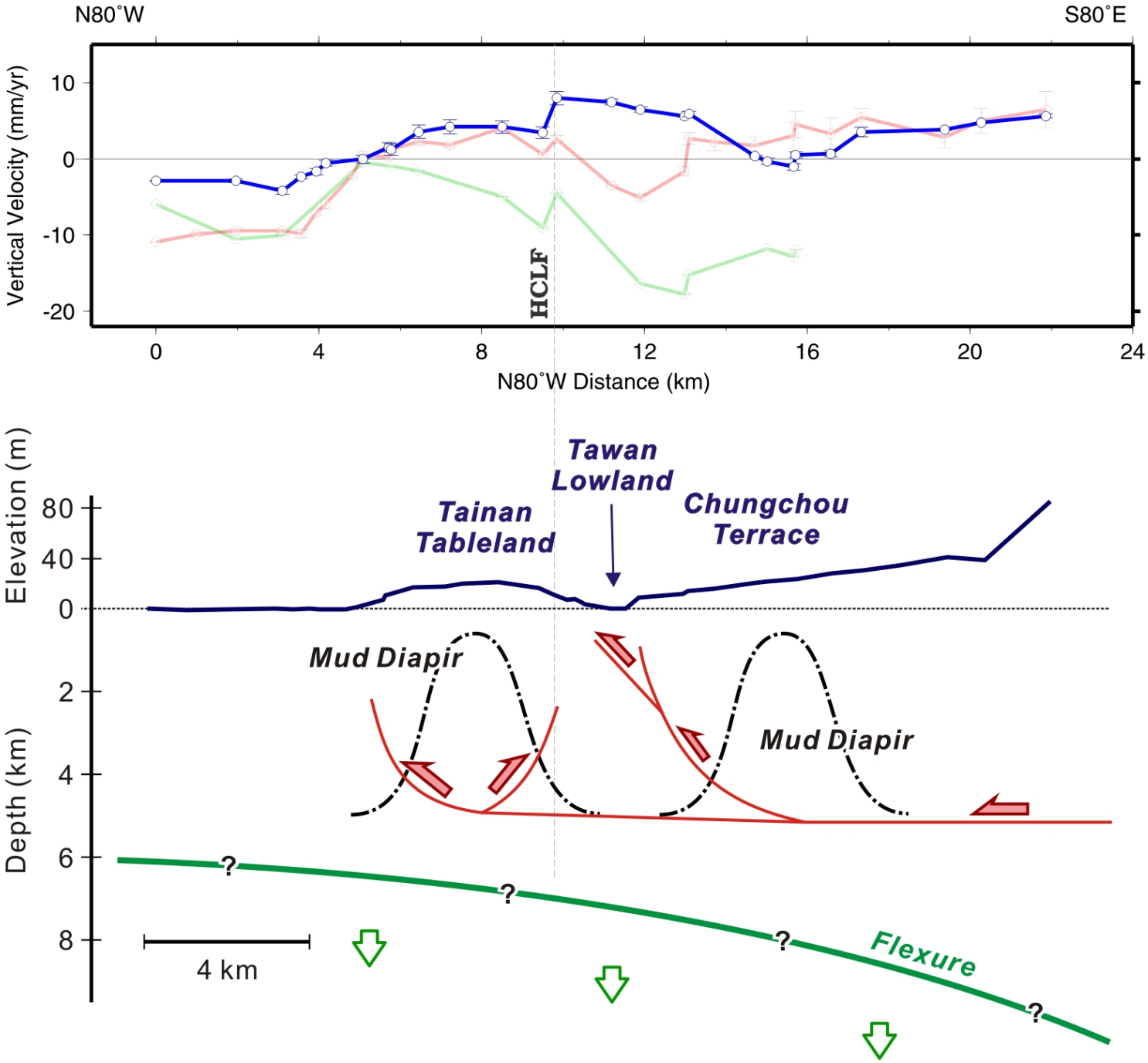
Phase I


N80˚W
S80˚E
Vertical Velocity (mm/yr)
10
0
-10
-20
HCLF
0
4
8
12
16
20
24
N80˚W Distance (km)
Elevation (m)
80
40
0
Tainan
Tableland
Tawan
Lowland
Chungchou
Terrace
Mud Diapir
Mud Diapir
Depth (km)
2
4
6
8
?
?
?
?
4 km
Flexure

Phase II

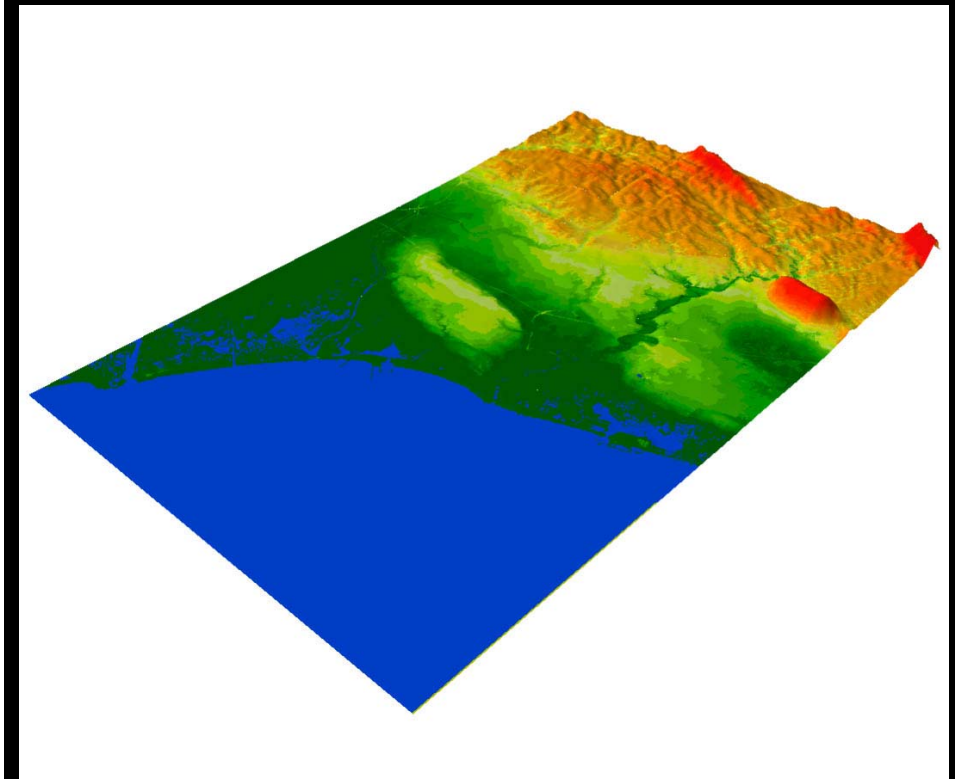

N80˚W
S80˚E
Vertical Velocity (mm/yr)
10
0
-10
-20
HCLF
0
4
8
12
16
20
24
N80˚W Distance (km)
Elevation (m)
80
40
0
Tainan
Tableland
Tawan
Lowland
Chungchou
Terrace
Mud Diapir
Mud Diapir
Depth (km)
2
4
6
8
?
?
?
?
4 km
Flexure

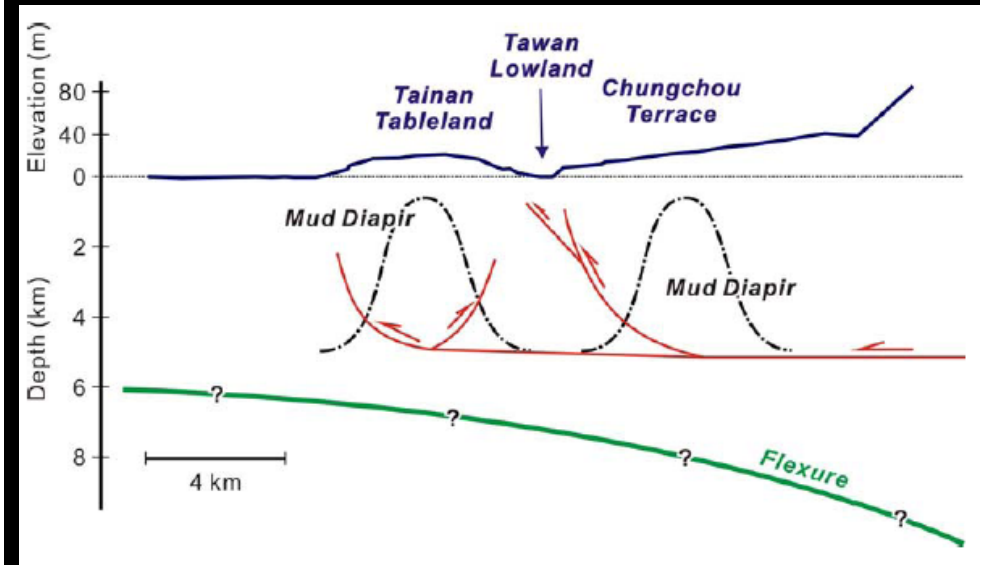
Phase III


N80˚W
S80˚E
Vertical Velocity (mm/yr)
10
0
-10
-20
HCLF
0
4
8
12
16
20
24
N80˚W Distance (km)
Elevation (m)
80
40
0
Tainan
Tableland
Tawan
Lowland
Chungchou
Terrace
Mud Diapir
Mud Diapir
Depth (km)
2
4
6
8
?
?
?
?
4 km
Flexure

Episodic fault creep in the Tainan tableland

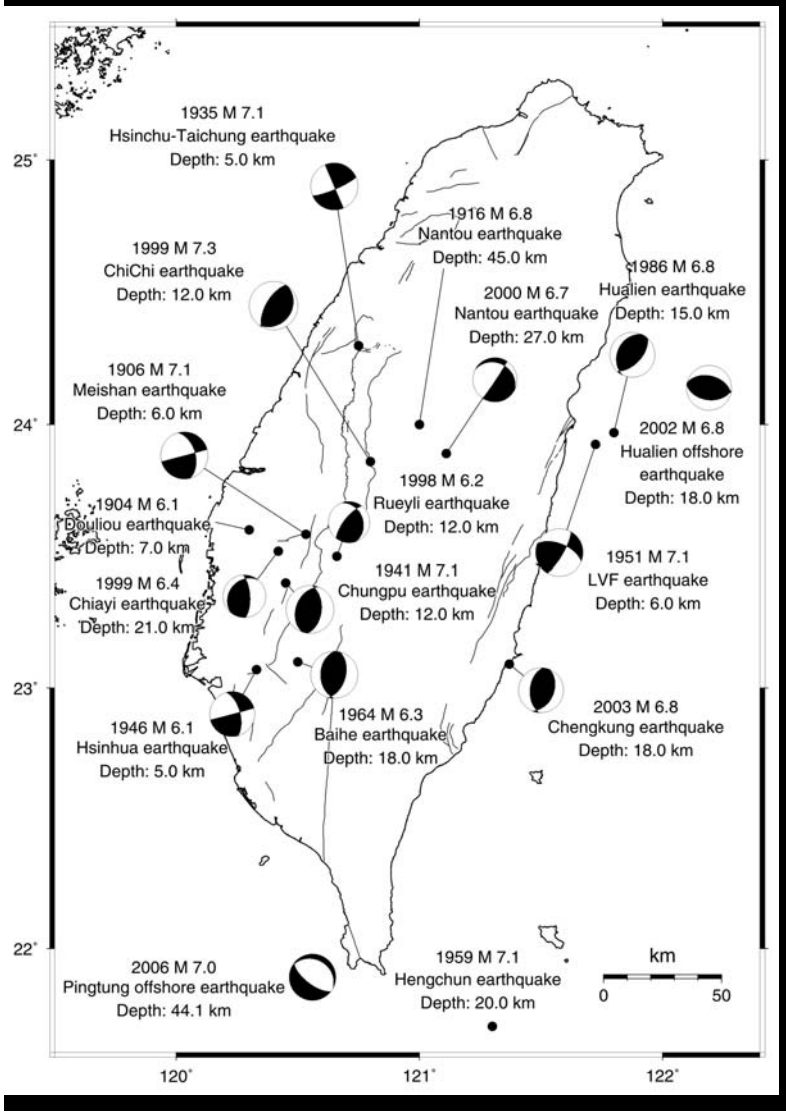
Creeping behavior of Tainan is controlled by the combination of subsidence of the foreland basin, development of mud diapir, and the fault motion

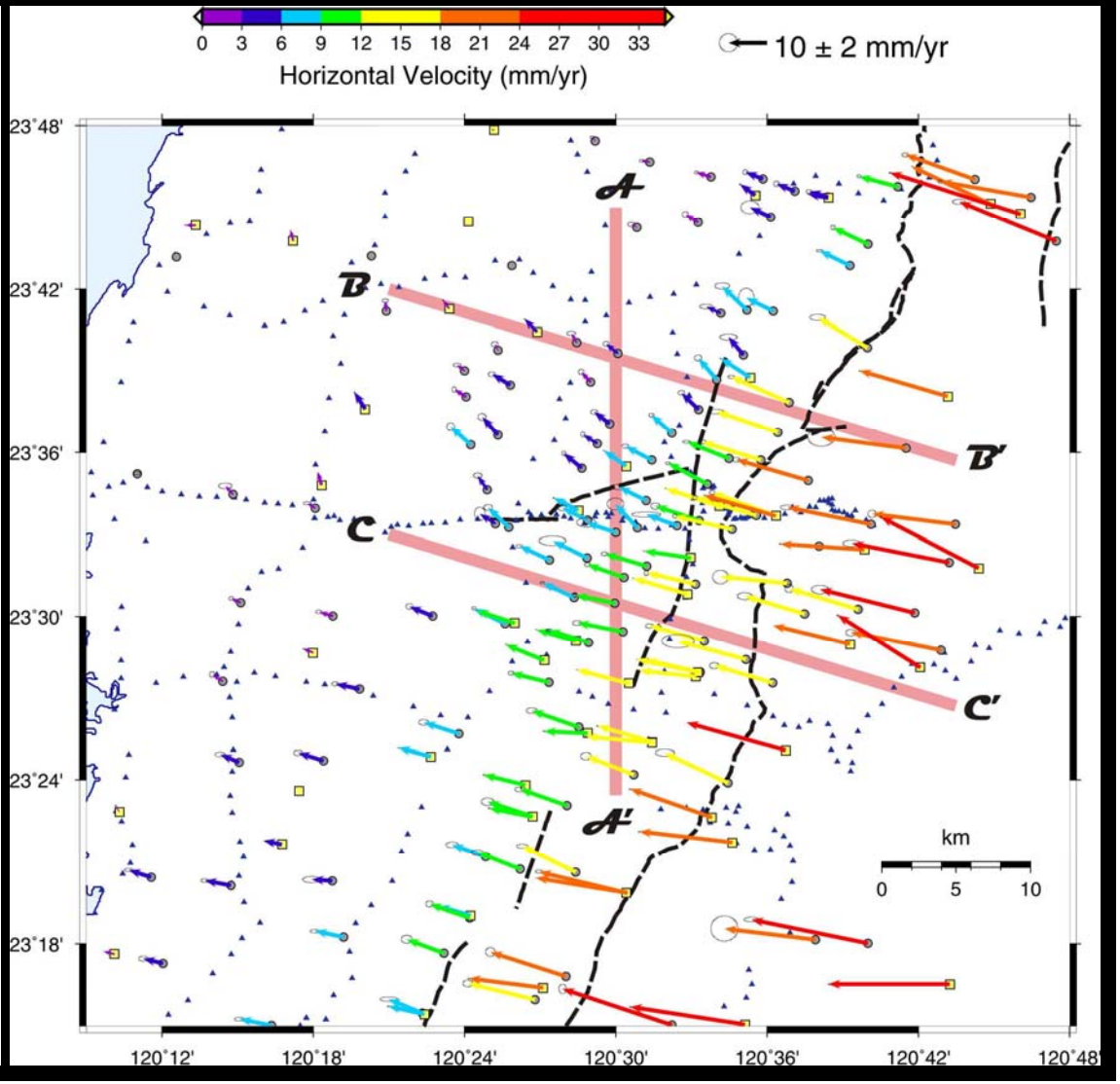




GPS Velocity Field in Chiayi Area

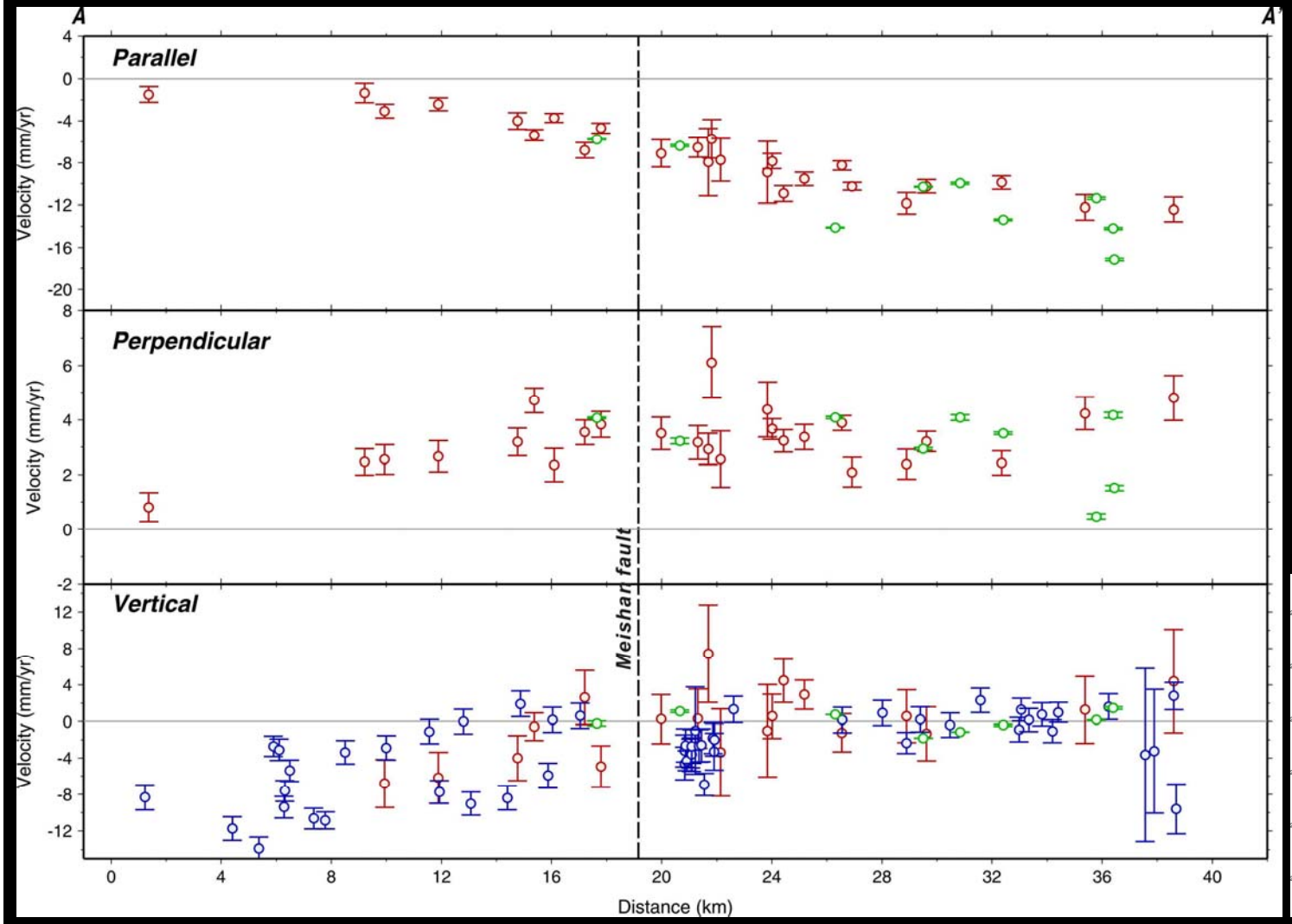
2002-2011



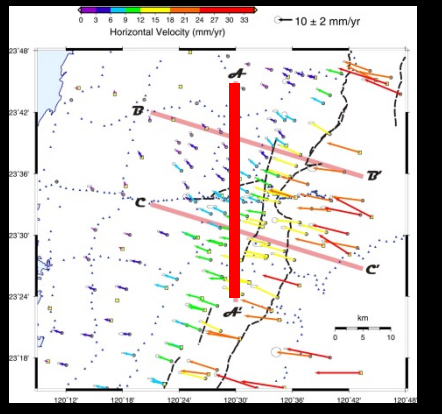


Profile A-A’

cross *Meishan* fault

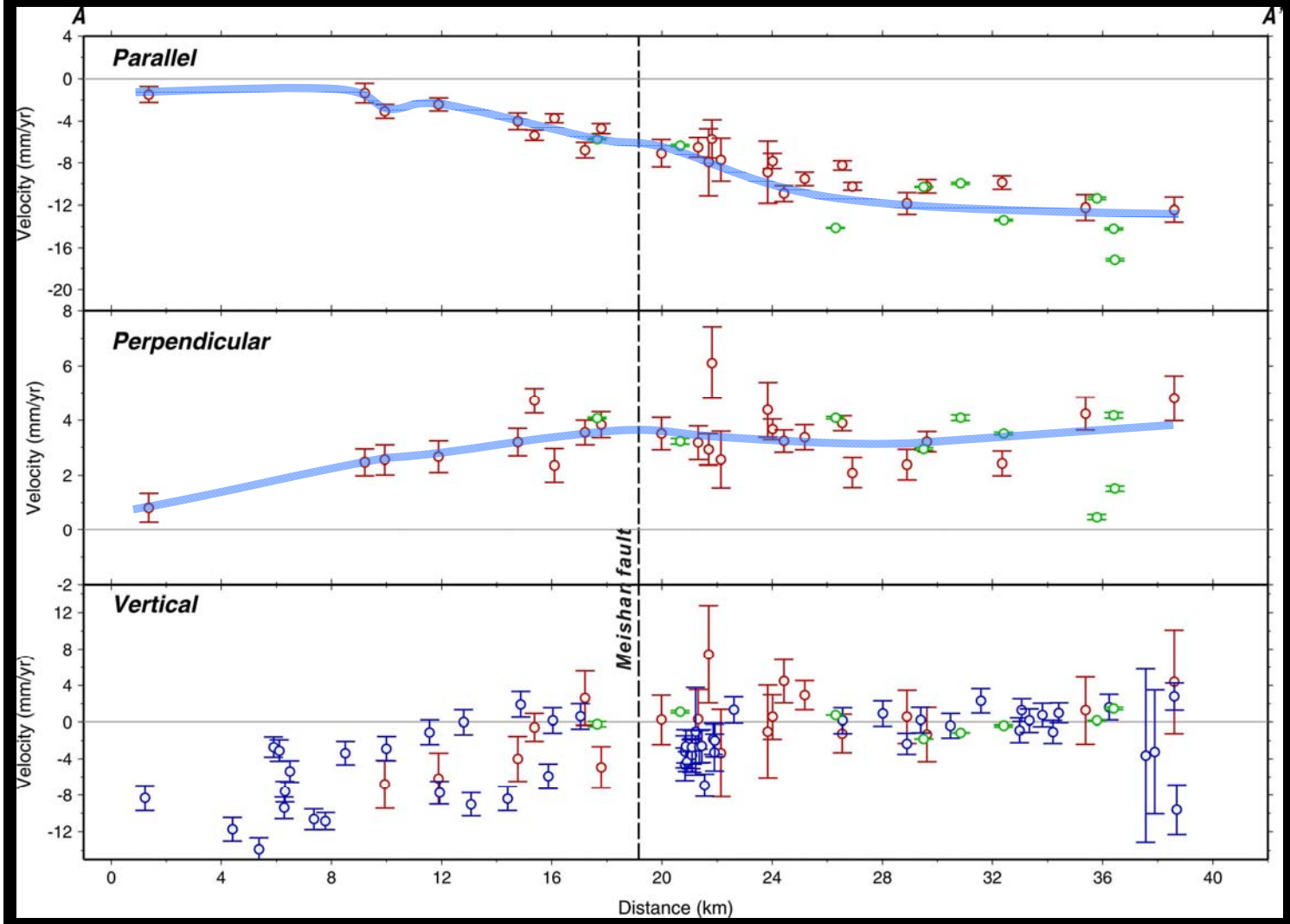


- campaign GPS
- continuous GPS
- leveling

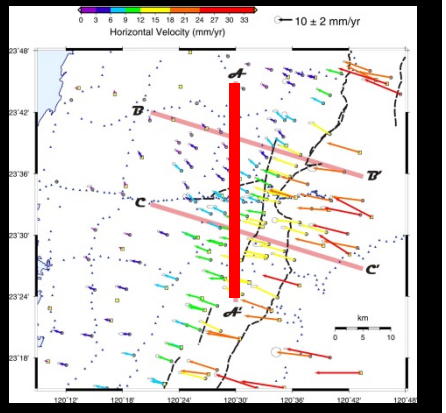


Profile A-A’

cross *Meishan* fault

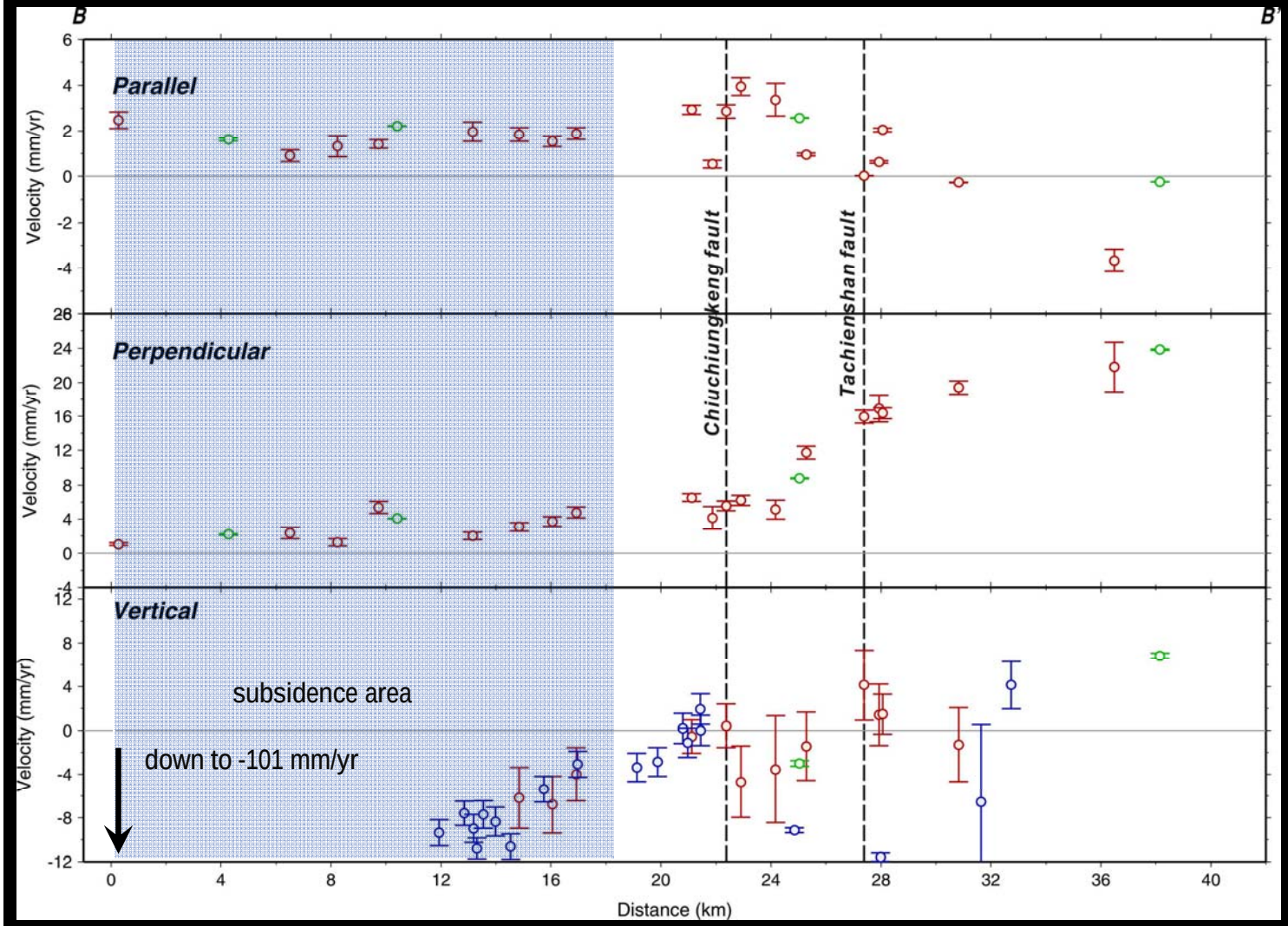


- campaign GPS
- continuous GPS
- leveling

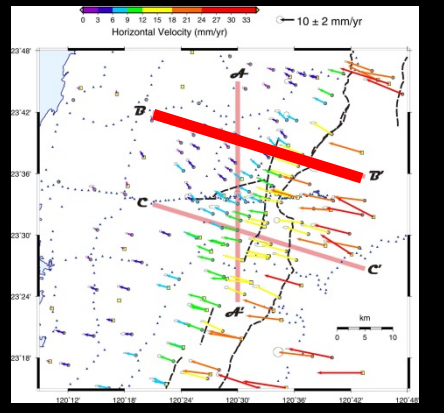


Profile B-B’

cross *Chiuchiungkeng* fault and *Tachienshan* fault

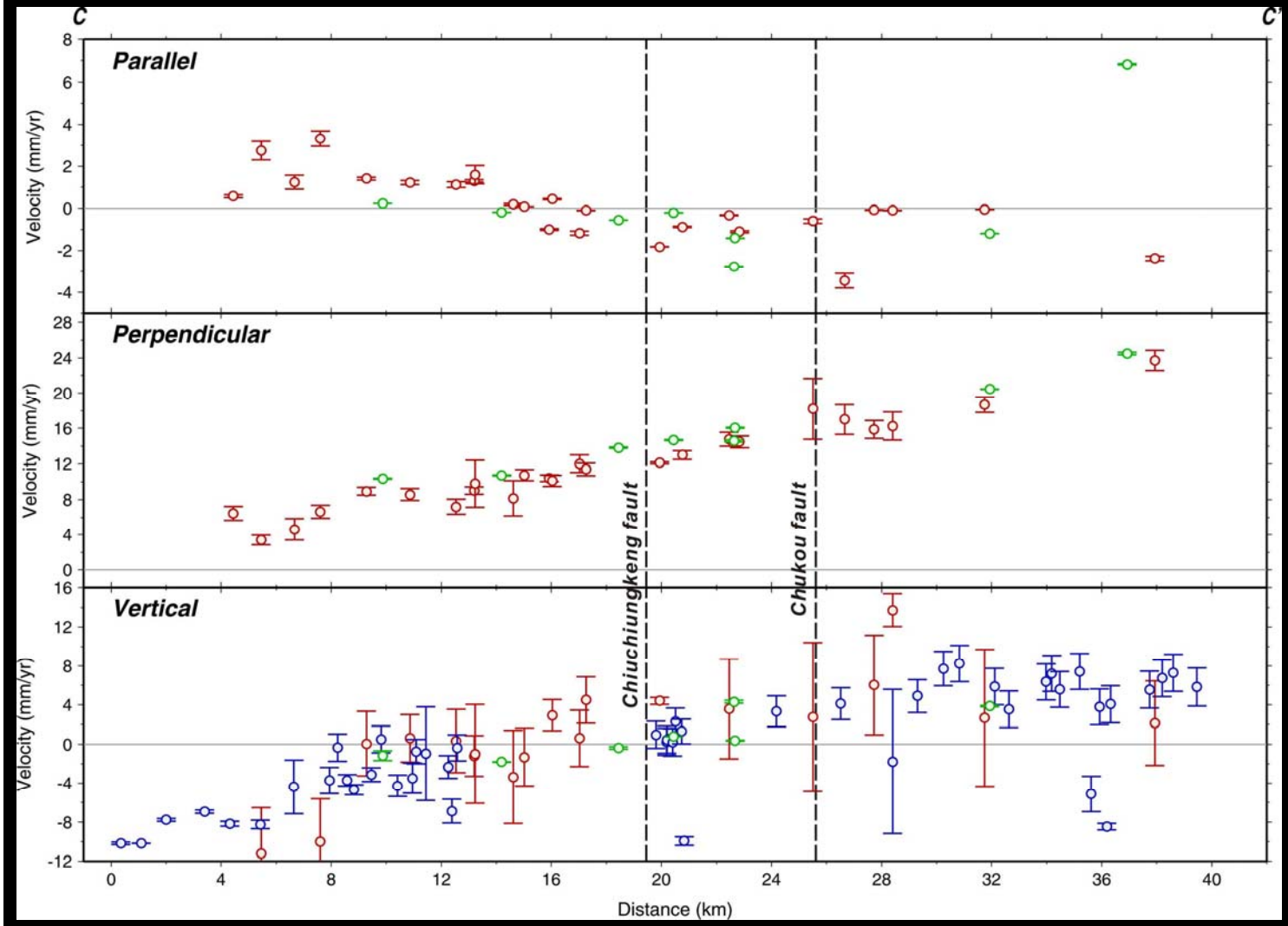


- campaign GPS
- continuous GPS
- leveling

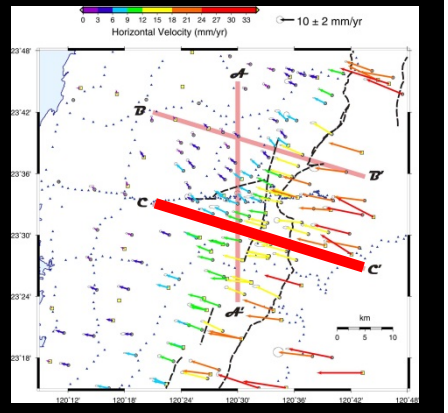


Profile C-C'

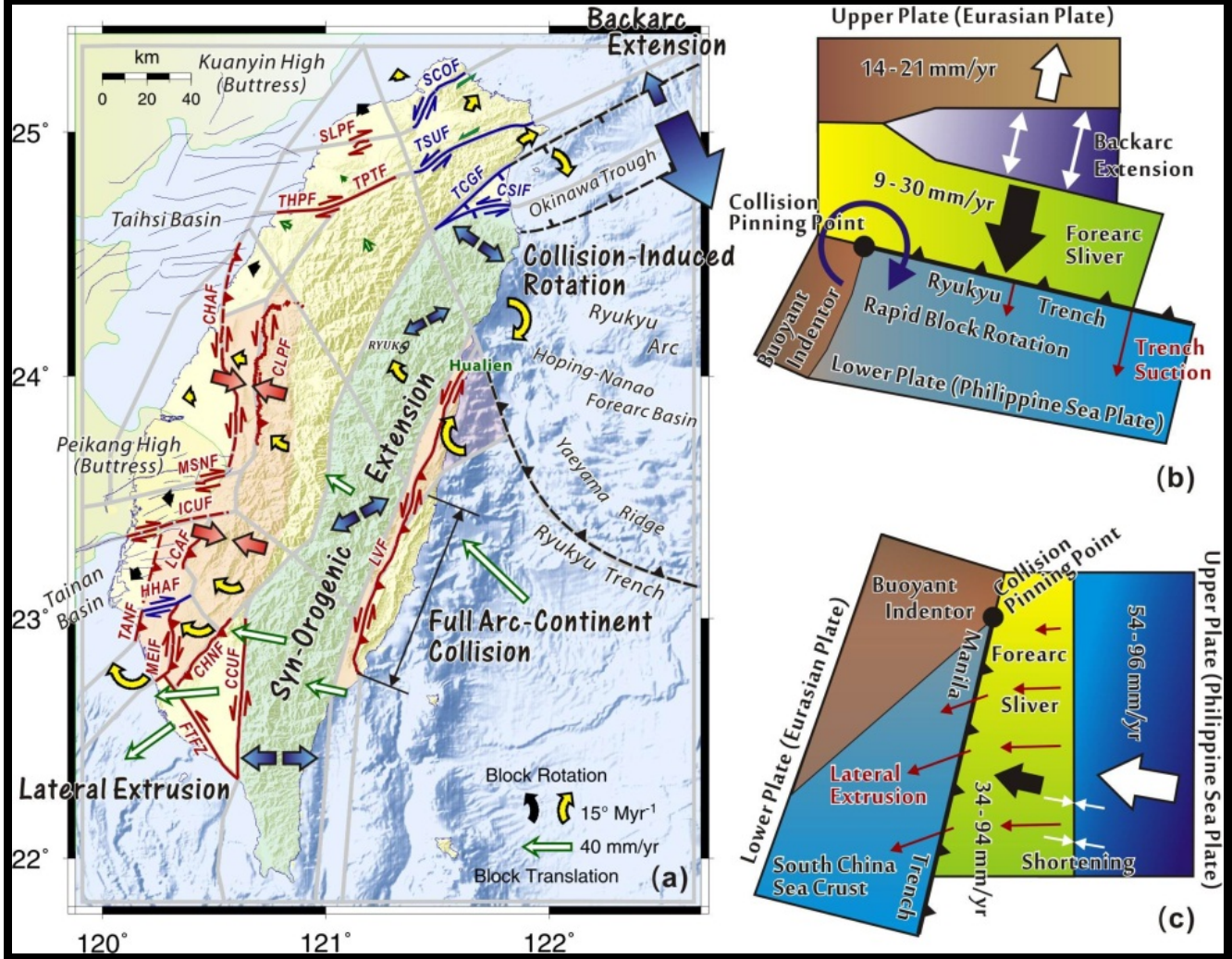
cross *Chiuchiungkeng* fault and *Chukou* fault



- campaign GPS
- continuous GPS
- leveling



Summary



1. High strain rate (~1.0 x 10^{-6}/year) for major thrusts and short recurrence intervals (20-200 years) for large earthquake in Taiwan.

2. Seismogenic structures: subduction and collision zones and reactivations of pre-existing structures.

3. Display wide range of fault-motion and earthquake spectrums.