Distribution of Seismic and Aseismic Slip on the Longitudinal Valley Fault

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Abstract

The Longitudinal Valley Fault (LVF) runs parallel to the East coast of Taiwan and accommodates about one third of the 8 cm/yr convergence rate between the Eurasian and the Philippine Sea plates. Due to the thrust component of slip, the fault zone is exhumed in the Coastal range. Deformation of anthropogenic features shows that aseismic creep accounts for a significant fraction of fault slip near the surface, but large Mw > 6.5 earthquakes, like in 1951 and 2003 show that a fraction of the slip is also seismic. Surface strain across the fault is monitored by creepmeters at one site and 21 permanent GPS stations. The creepmeter measurements confirm that the fault creeps near the surface, and show in addition that the creep rate varies seasonally. In this project existing creepmeter, strong-meters and GPS data have been analyzed to precisely document the spatio-temporal evolution of slip on the fault. Data are inverted for the temporal evolution of slip at depth using the Principal Component Analysis Inversion Method (PCAIM) developped by Kositsky and Avouac (2009). The focus was on the portion of the fault which is undergoing aseismic creep and where the creep rate shows seasonal fluctuations. This analysis aims at shedding light on the mechanical properties of the fault zone and how they relate to lithological and hydrological factors.

These primary results show that in the south, the LVF can be divided in three different domains: (a) a deep domain, where the fault creeps at high rate during the interseismic, (b) an intermediate domain with a portion that creeps and a portion that was locked before the Mw 6.8 2003 Chengkung earthquake, (c) and finally, a shallow portion of the fault (depth less than about 1-2 km) moving slowly during the interseismic (relative to deeper area) and producing a large amount of slip during the postseismic period. This shallow portion is also characterized by seasonal variation of creep with rates notably larger during wet seasons suggesting a dependency to fluid pore-pressure variations.

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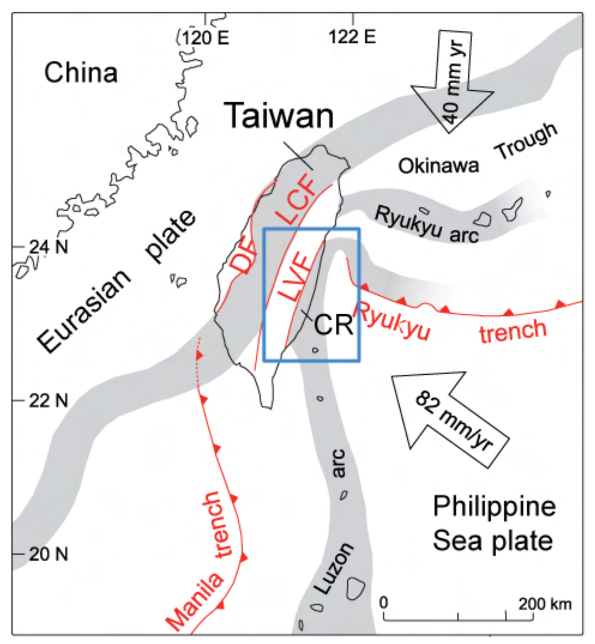
Interseimic displacement from GPS (horizontal component)



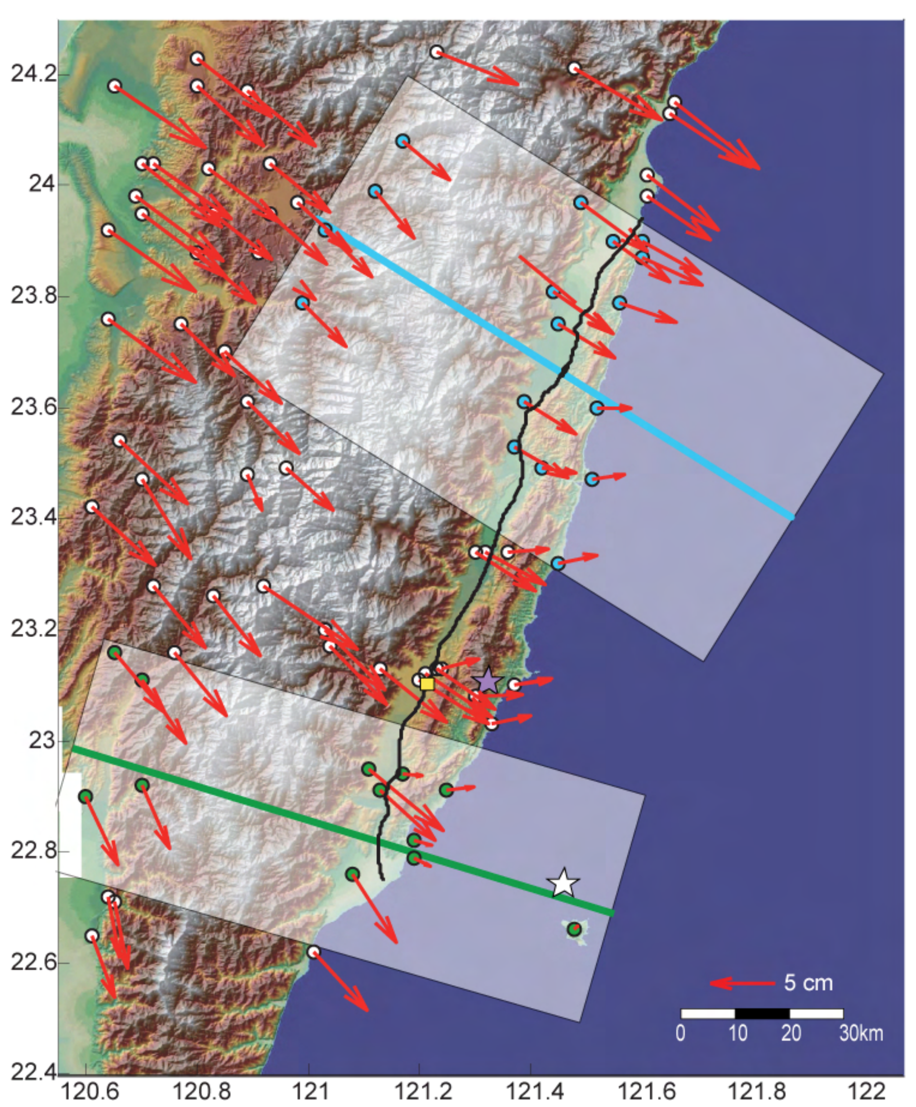
(a) Tectonic snapshot of Taiwan

(modified from Shyu et al, 2005).

Taiwan is the product of the arc-continent collision propagating southward. In the north the Philippine Sea plate subducts beneath the Chinese continental margin at the Ryukyu trench. In the south, the China Sea subducts eastward beneath the Philippine Sea plate at the Manila trench, generating the Luzon arc.The LVF is the suture between the Eurasian and the Philippine sea plates.

LVF = Longitudinal Valley Fault LCF = Lishan-Chaochou Fault DF = Deformation Front.

(b) Horizontal velocity field



Legend

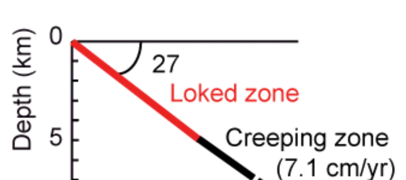
- GPS stations
- 2003 Chengkung earthquake
- 2004 Lutao earthquake
- Chinyuan creepmeter
- Horizontal displacement relative to the Philippine plate (data from Yu et al, 2001)
- Longitudinal Valley Fault (LVF)

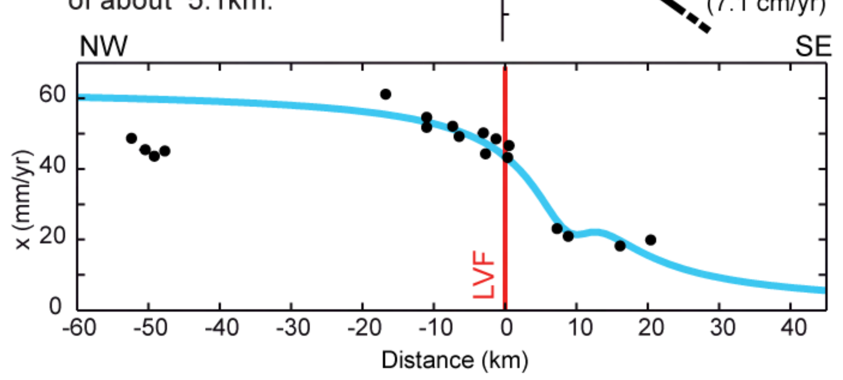
The velocity field suggest some differences between the north and the south of the LVF. In the north horizontal velocities vary smoothly across the LVF suggesting the fault is locked close to surface. In the south, the velocity is discontinuous across the LVF, confirming the fault creeps at surface.

(c) Dislocation Model (Okada. 1985)

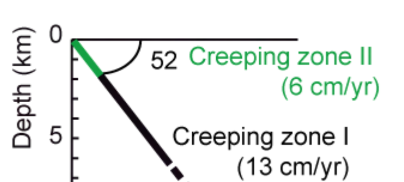
Using a dislocation in an elastic half-space (back-slip approach), horizontal velocities have been inverted (Savage, 1983 ; Okada, 1985).Two sections have been considered, troughly perpendicular to the strike of the fault.

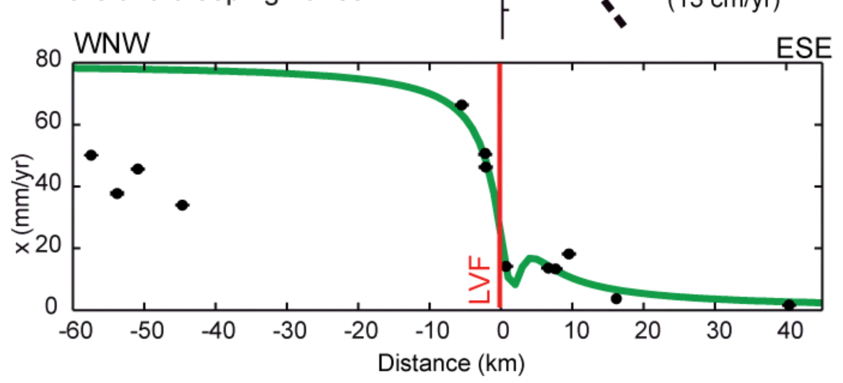
Northern Section
the fault is locked from the surface to a depth of about 5.1km.





Southern Section
no fully locked zone is needed, instead there are two creeping zones.

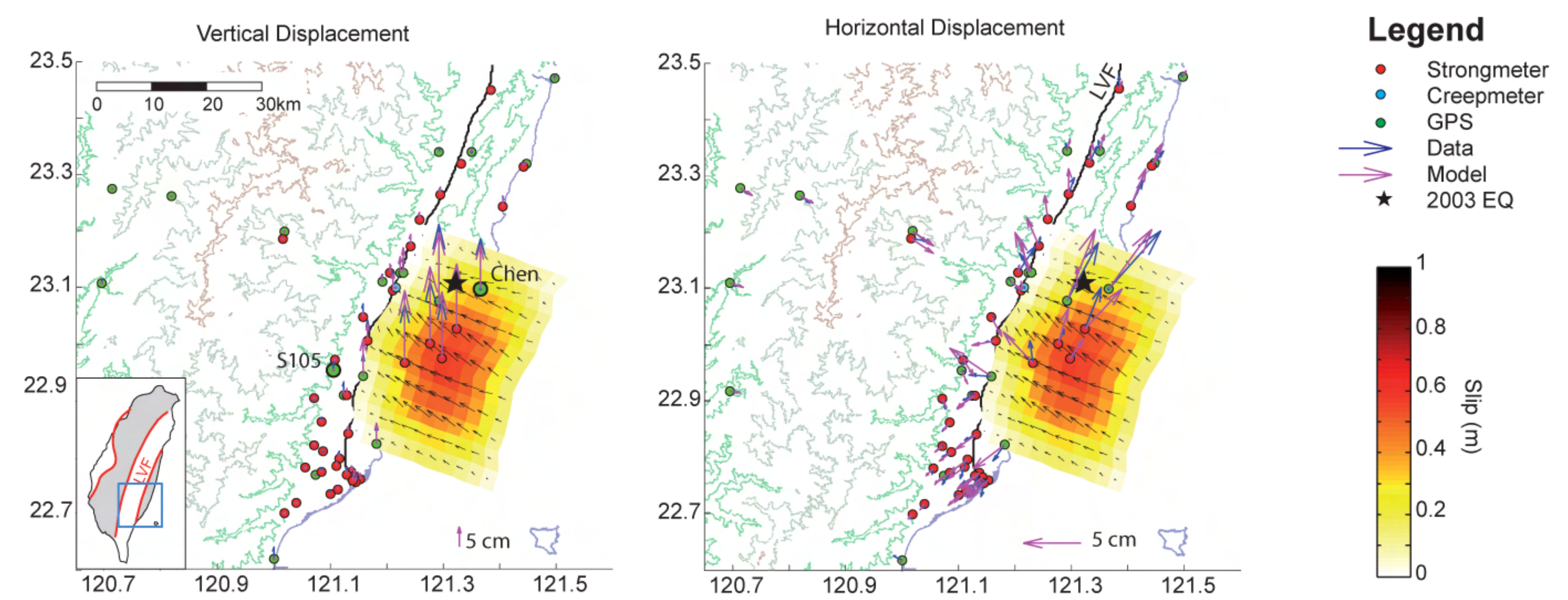




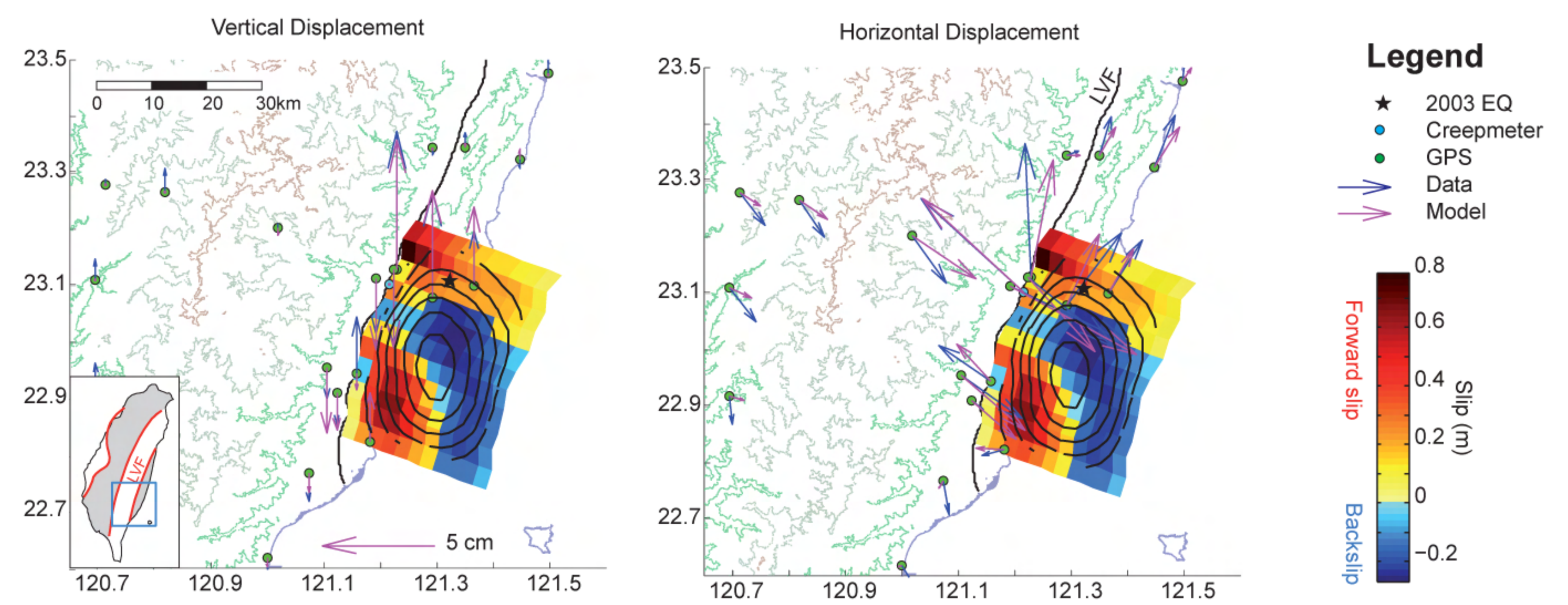
Mw 6.8 2003 Chengkung Earthquake

Modeled displacement at depth for the coseismic and postseismic history following the Chenkung earthquake. Result are obtained using PCAIM , developped by Kositsky and Avouac (2009).

(a) Coseismic Displacement



(b) Postseismic Displacement



Based on the model, no postseismic slip occurs in the area of high coseismic displacement, instead backslip is observed. The southward rupture propagation can explain the forward slip in south area, at shallow depth: stress accumulated during the coseismic is realeased during the postseismic period. Then, accordingly to the field observations, the model shows that the rupture did not reach the surface, instead slip occurs during the postseismic.

Seasonal variations of creep

(a) Decomposition of times-series

$$u^i(u) = u_o^i + v^i t + \sum_j h_j^i \mathcal{H}(t-t_j)$$

Offset Longterm Coseismic

$$+ \sum_k r_k^i \mathcal{H}(t-t_k) \log\left(1+\frac{(t-t_k)}{\tau}\right)$$

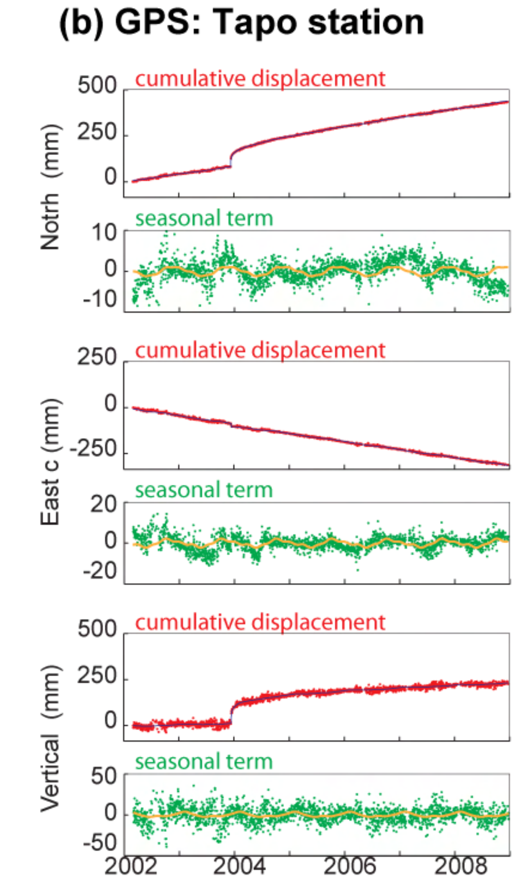
Postseismic

$$+ \sum_p \left(s_p^i \sin\left(\frac{2\pi t}{T_p}\right) + c_p^i \cos\left(\frac{2\pi t}{T_p}\right)\right)$$

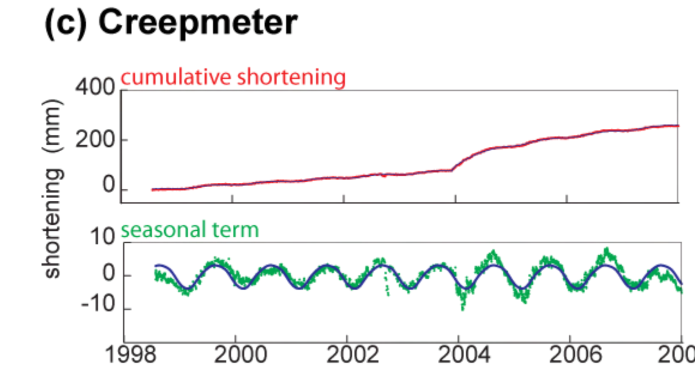
Seasonal Term

After removing the longterm velocity, the coseismic and the postseismic displacement a prominent component still remains in the geodetic data (in some GPS stations and in the creepmeter), and it is strongly related to the seasons.

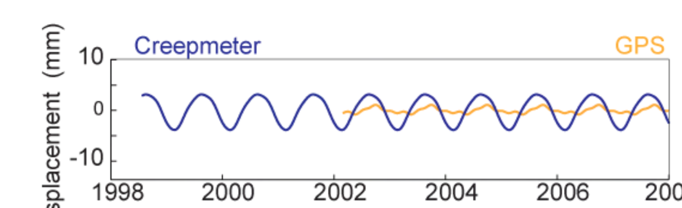
(b) GPS: Tapo station



(c) Creepmeter



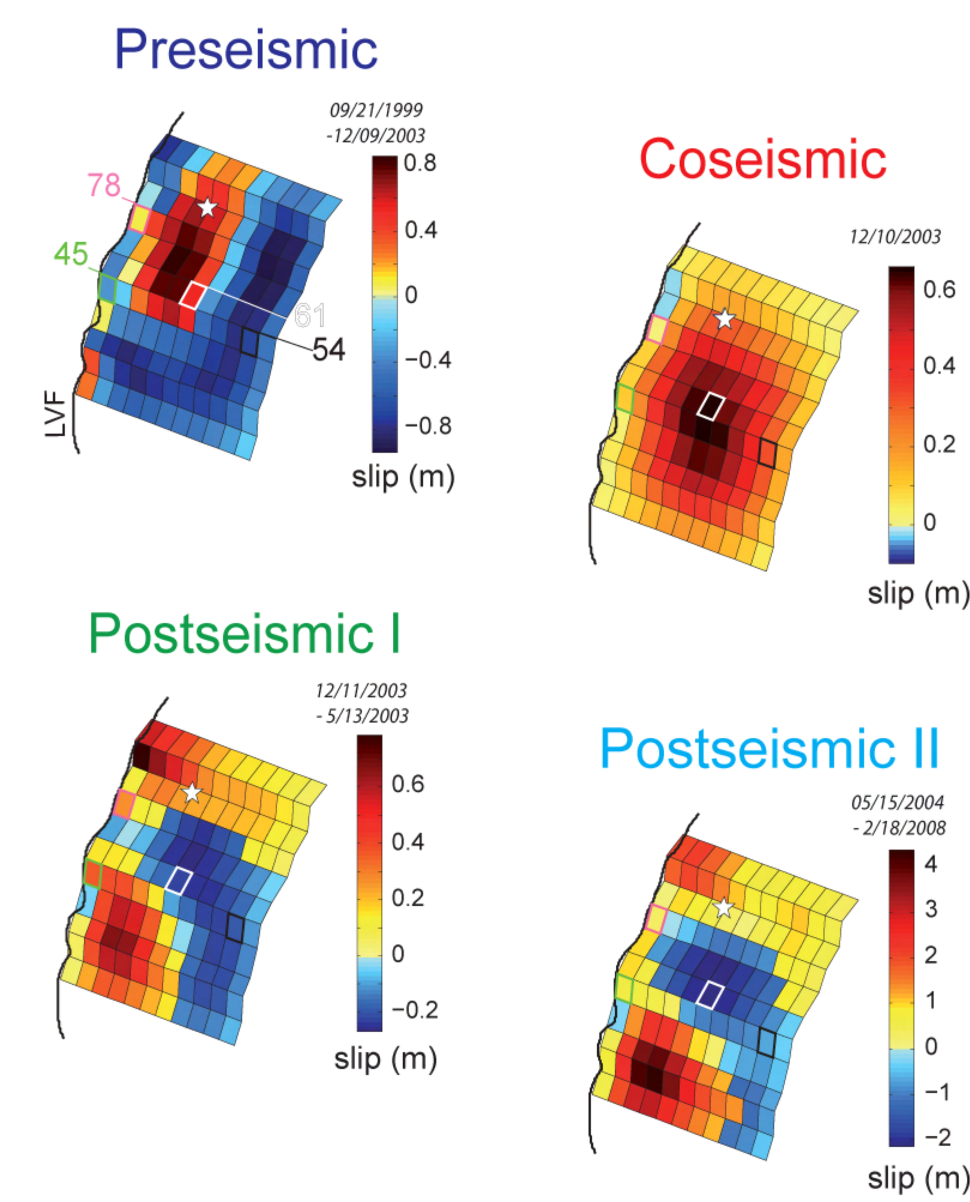
(d) Comparison GPS/Creepmeter



Depth of the creeping zone influenced by the meterological factors can be unferring by inverting thoses seasonal signal

Slip History at depth

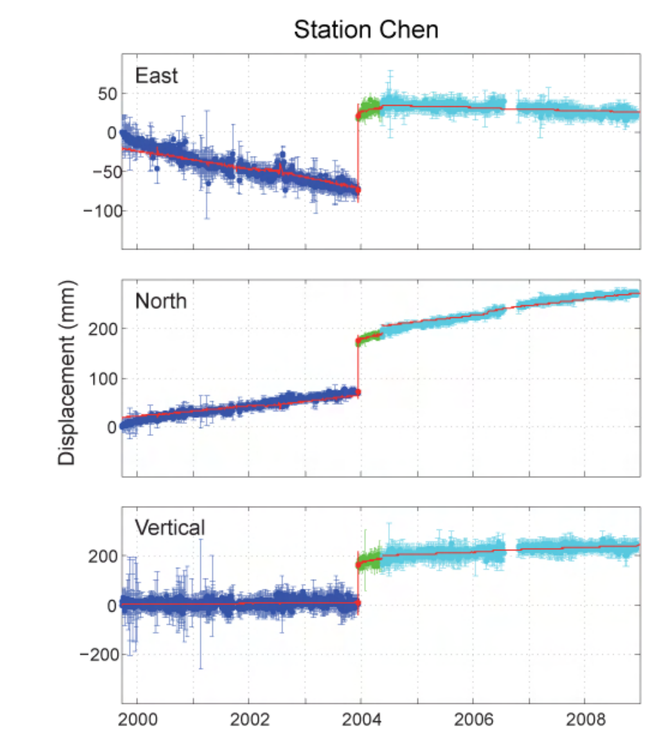
(a) Cumulative slip for 4 periods

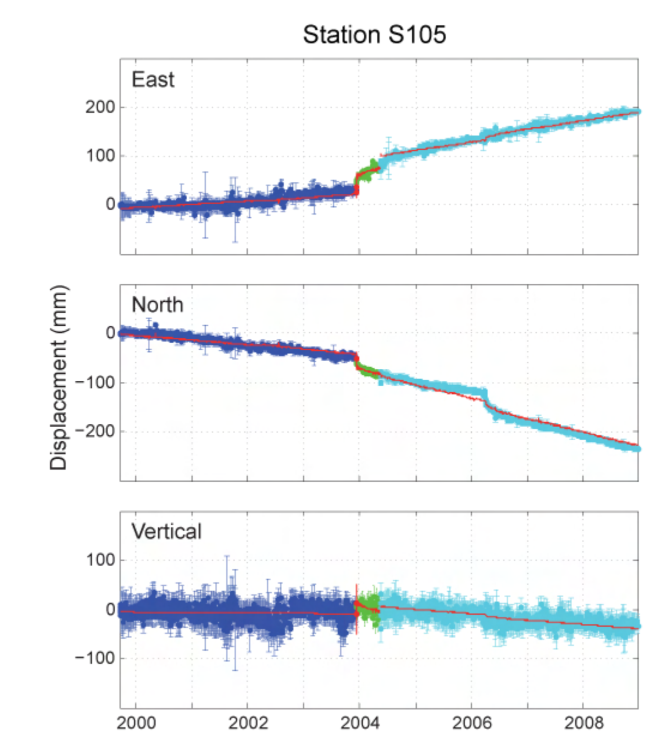


Inversion models show that the 2003 Chengkung earthquake ruptured a zone that was locked before the event. Shallow creeping zone acted as a barrier during the 2003 earthquake. and seem to cumulate less quantity of slip during the interseismic period, releasing the deficit slip during the postseismic.

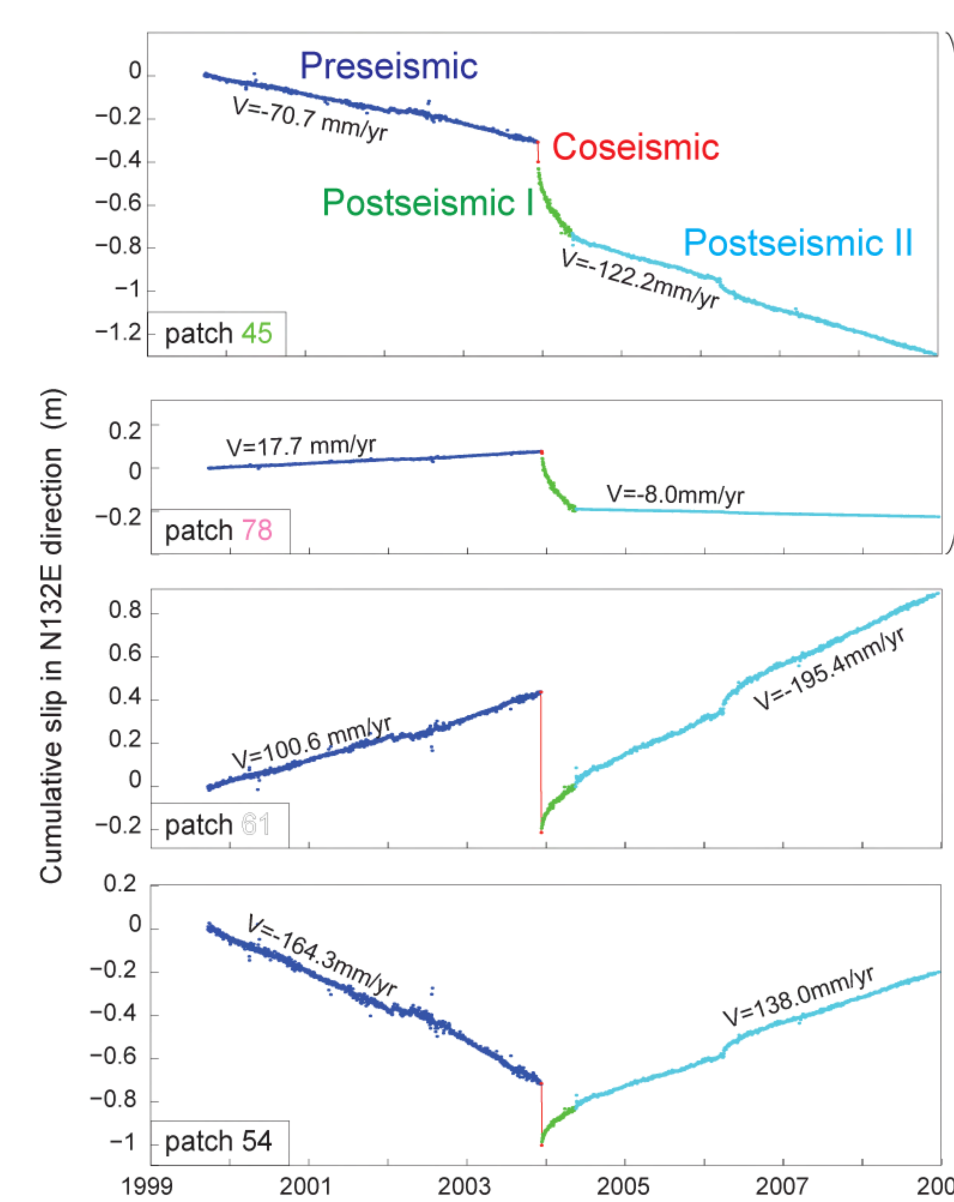
(b) Data fit

Figures showing how well the model fit the data for 2 sations on both sides of the fault (figure (a) in "Mw6.8 2003 Chengkung earthquake")





(c) Detailed slip history for 4 patches



Patch 45 & 78
represent the motion on the fault at shallow depth and the spatial variability of surface creep. For both patches, almost no slip is observed during the coseismic and a high slip rate is recorded during the postseismic I. But different behaviors are observed for the preseismic ans postseismic II periods: patch 45 creeps and patch 78 seems to be locked. Indeed, patch 78 is in the stress shadow of the locked zone. i

Patch 61
corresponds to location of the higher coseismic displacement. The modeling suggests that this patch was locked before and after the earthquake (backslip) and just move during the even.

Patch 54
localized in the deep creeping zone, shows a high creeping rate before the event. A Jump is observed during the event and then the area acts in backslip.