

Subduction et Géodésie GPS

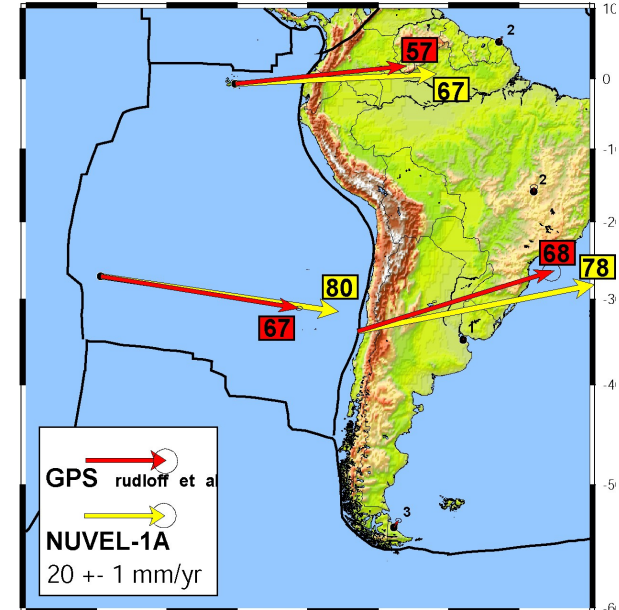
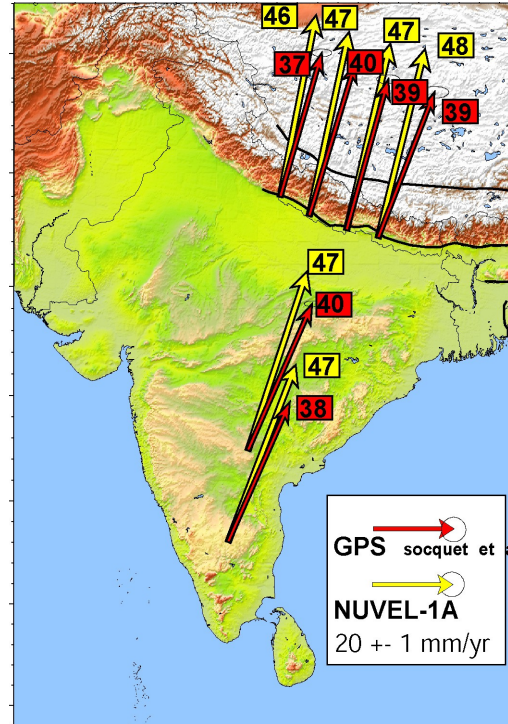
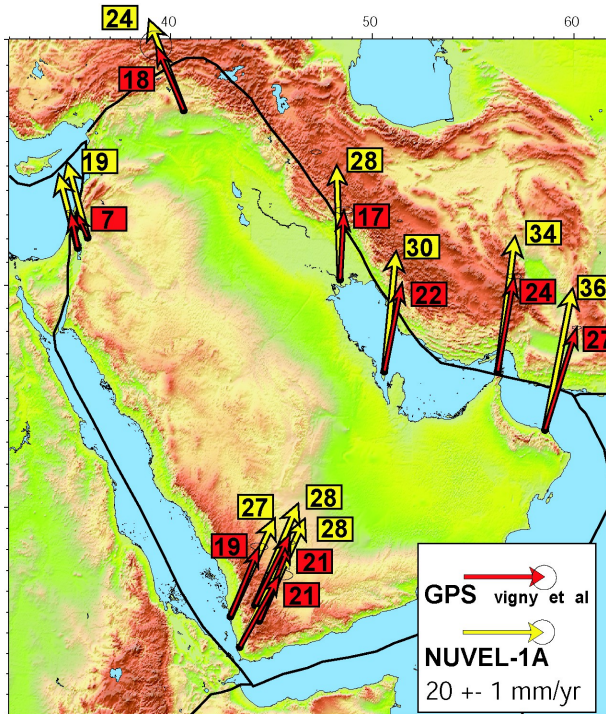
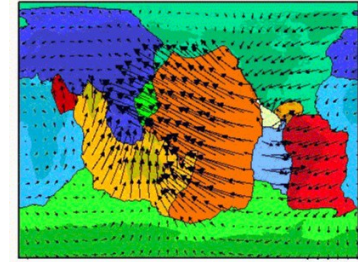
Christophe VIGNY

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<http://www.geologie.ens.fr/~vigny>

GPS : la tectonique des plaques

À grande échelle: les plaques

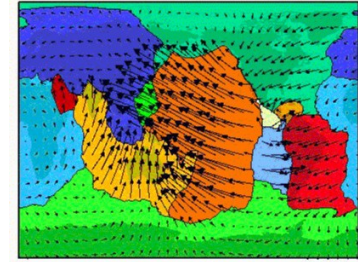


GPS trouve Arabie, Inde et Nazca plus lentes actuellement

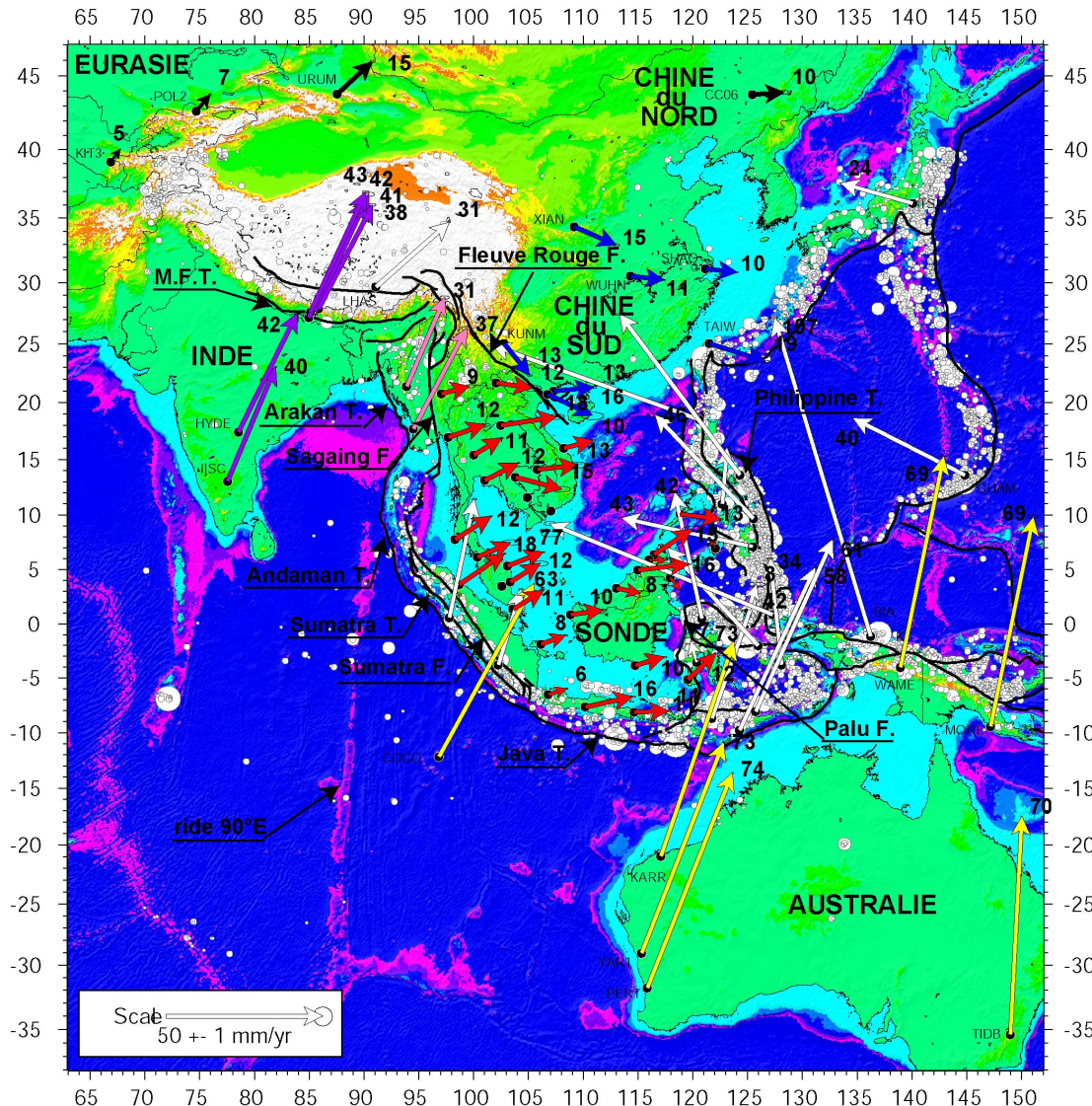
Arabie et Inde => ralentissement

Nazca => incertitude ?

GPS : la tectonique des plaques



À grande échelle: les micro-plaques ou blocs



Le bloc de la sonde:

=> ce bloc est indépendant de l'Eurasie et s'en éloigne à ~1cm/an vers l'Est

La Chine du Sud:

=> est aussi indépendante de l'Eurasie et s'en éloigne à ~1cm/an vers l'Est également.

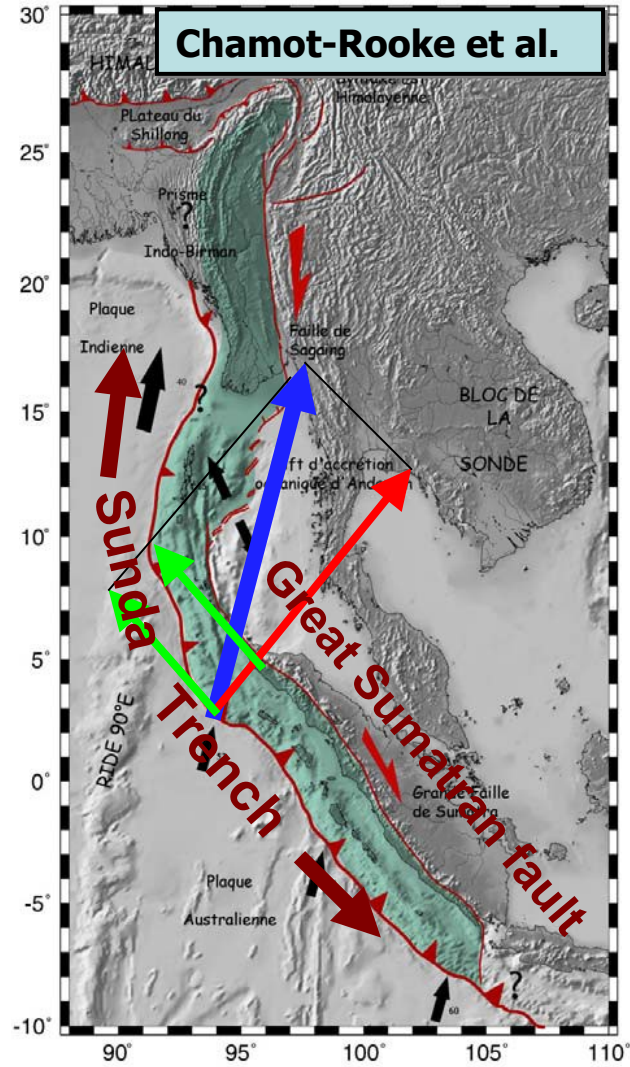
L'INDE:

=> Seulement 4 cm/a par rapport à l'Eurasie et seulement 3.5 cm/an par rapport à Sunda

BURMA platelet (or sliver):

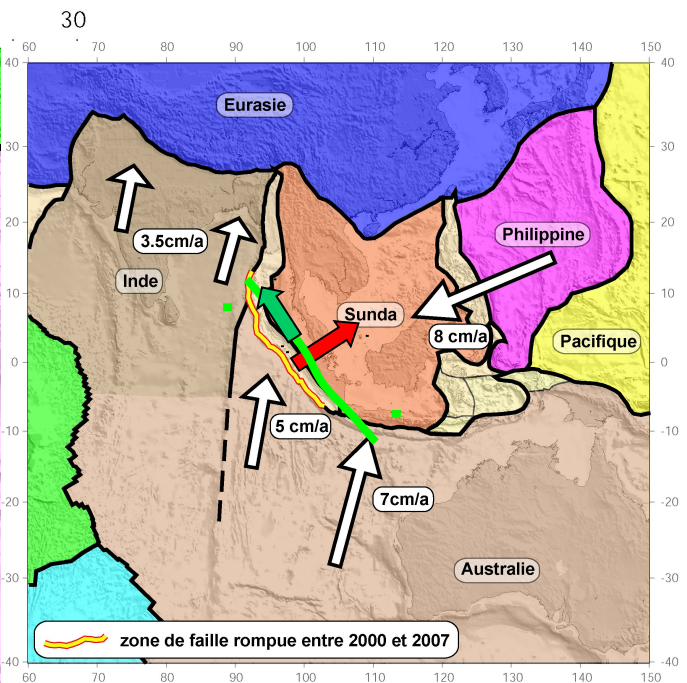
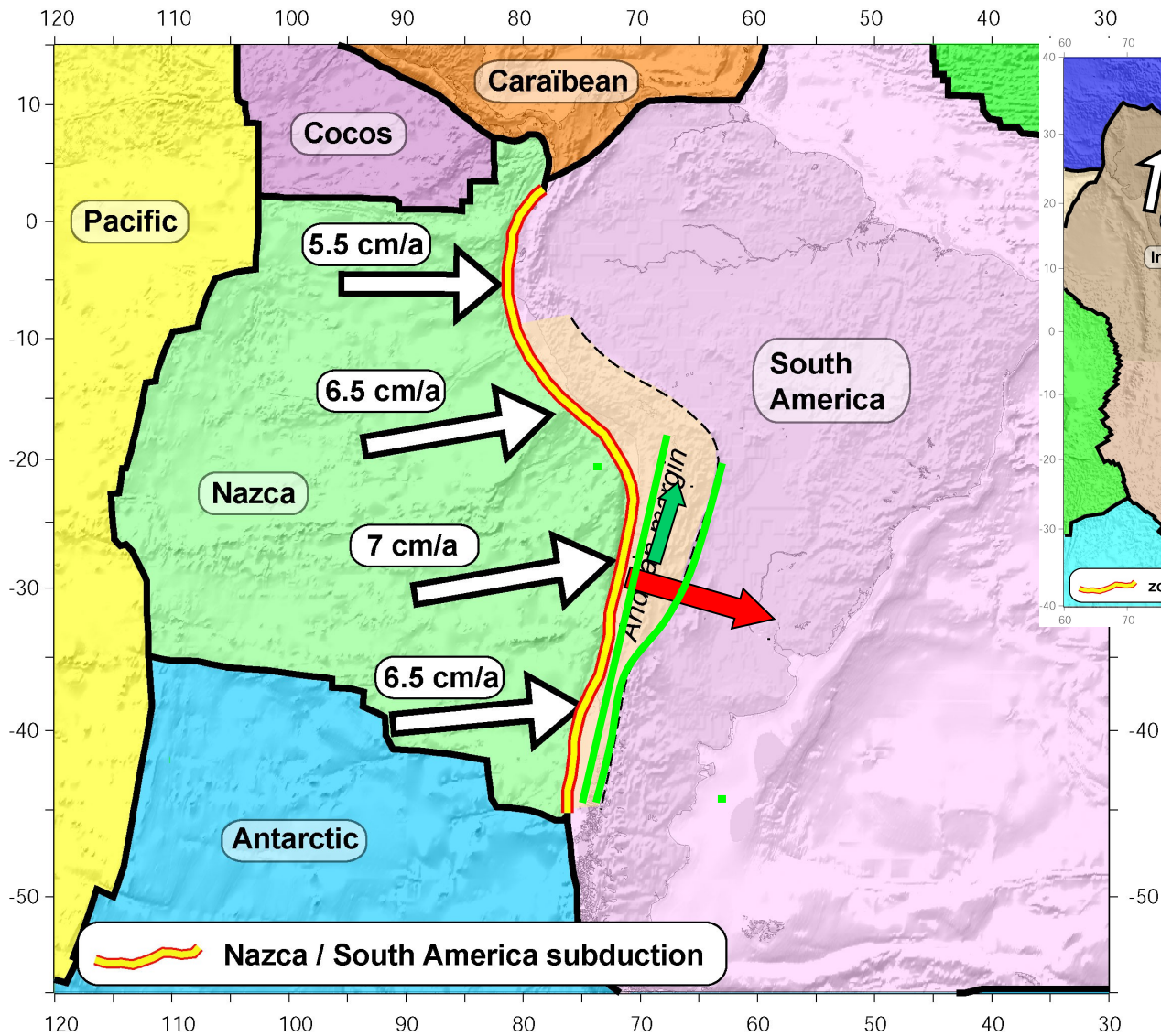
=> Ni Inde ni Sonde (encore moins Eurasie)

partitionnement



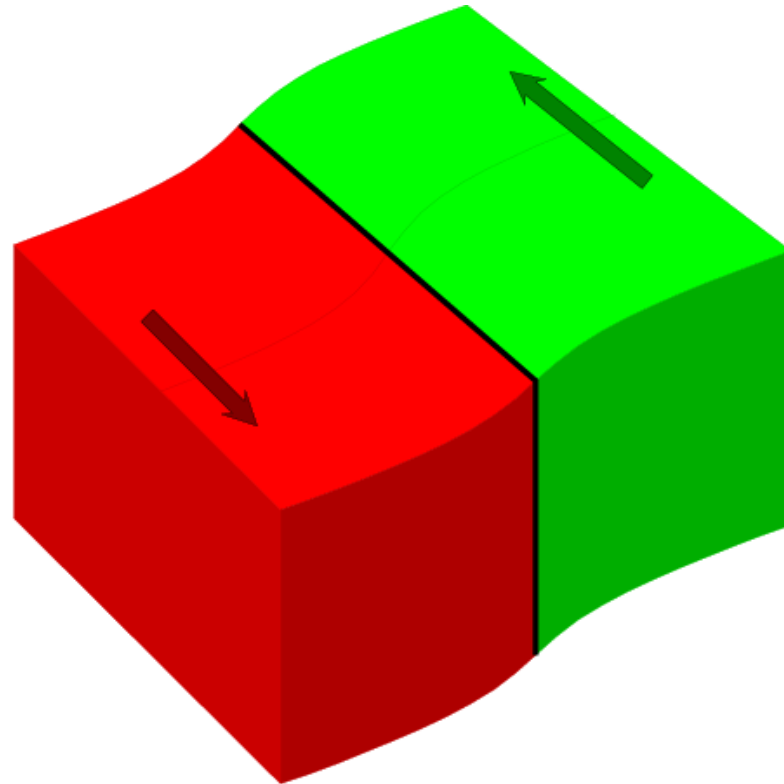
Motion Partitioning

Problème 1: Relation obliquité/partitionnement ?



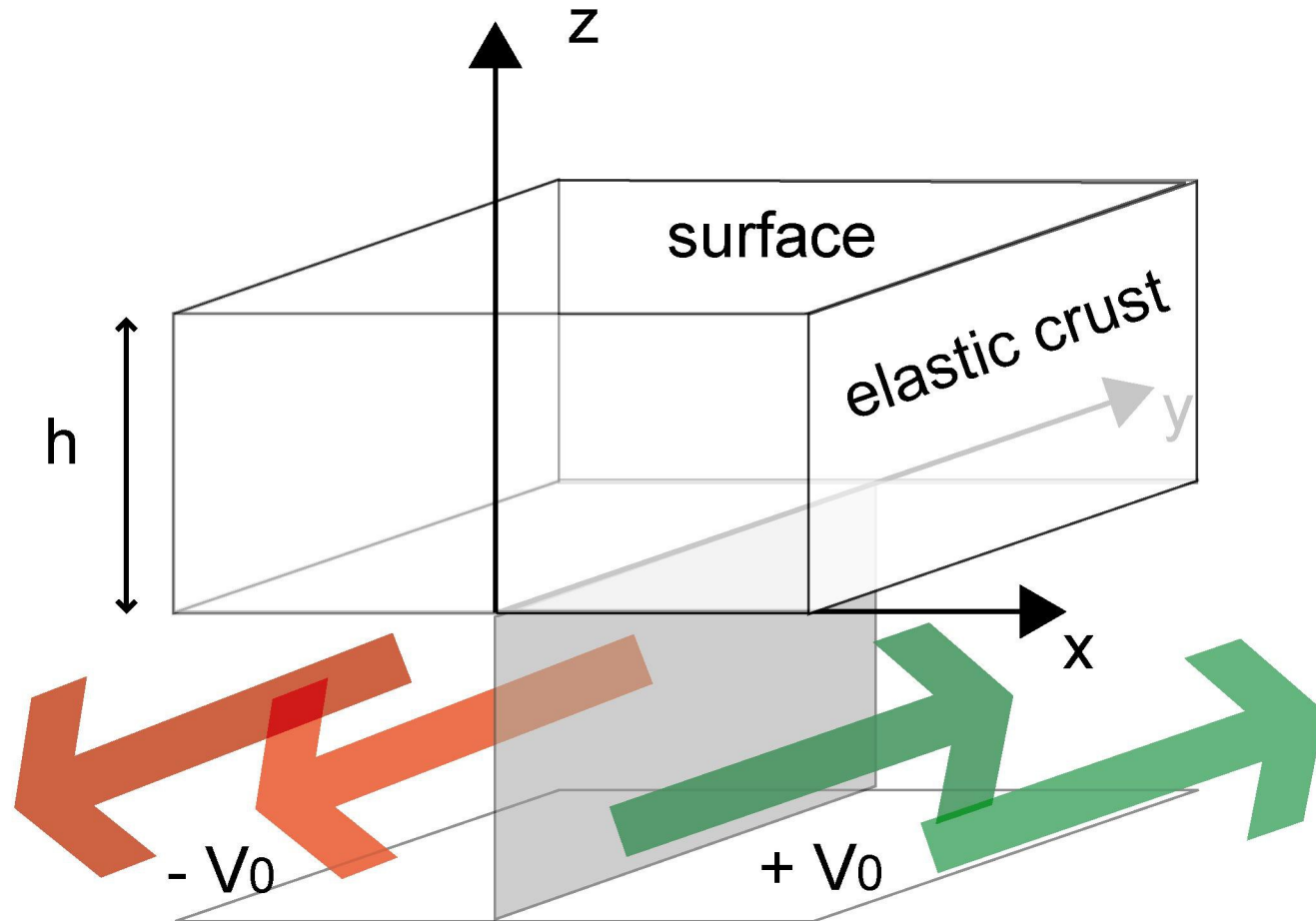
Problème 2: accumulation de déformation élastique

version simple : Faille bloquée verticale coulissante



Quelle est la forme de la courbe de déformation ?

Formulation mathématique du problème



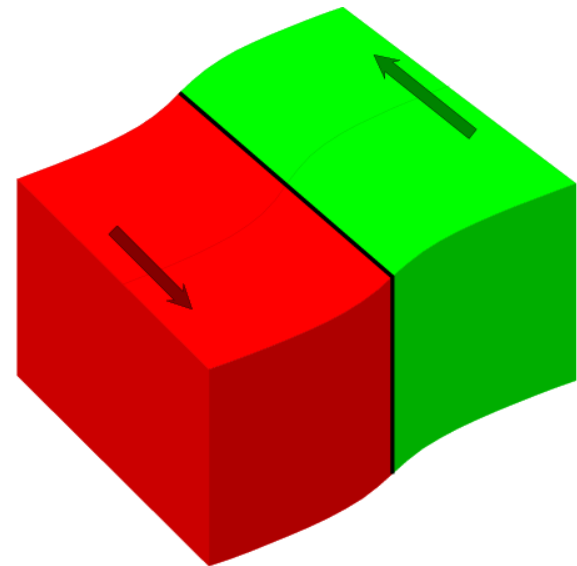
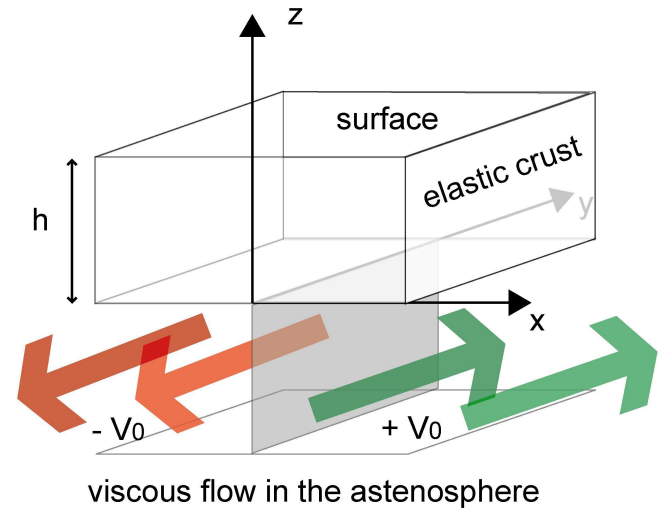
viscous flow in the asthenosphere

Solution : arctangente

$$U_y = K \arctang (x/z)$$

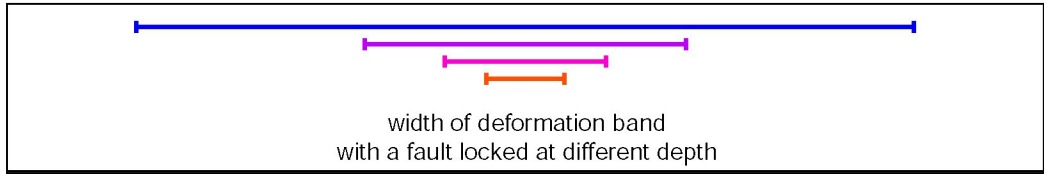
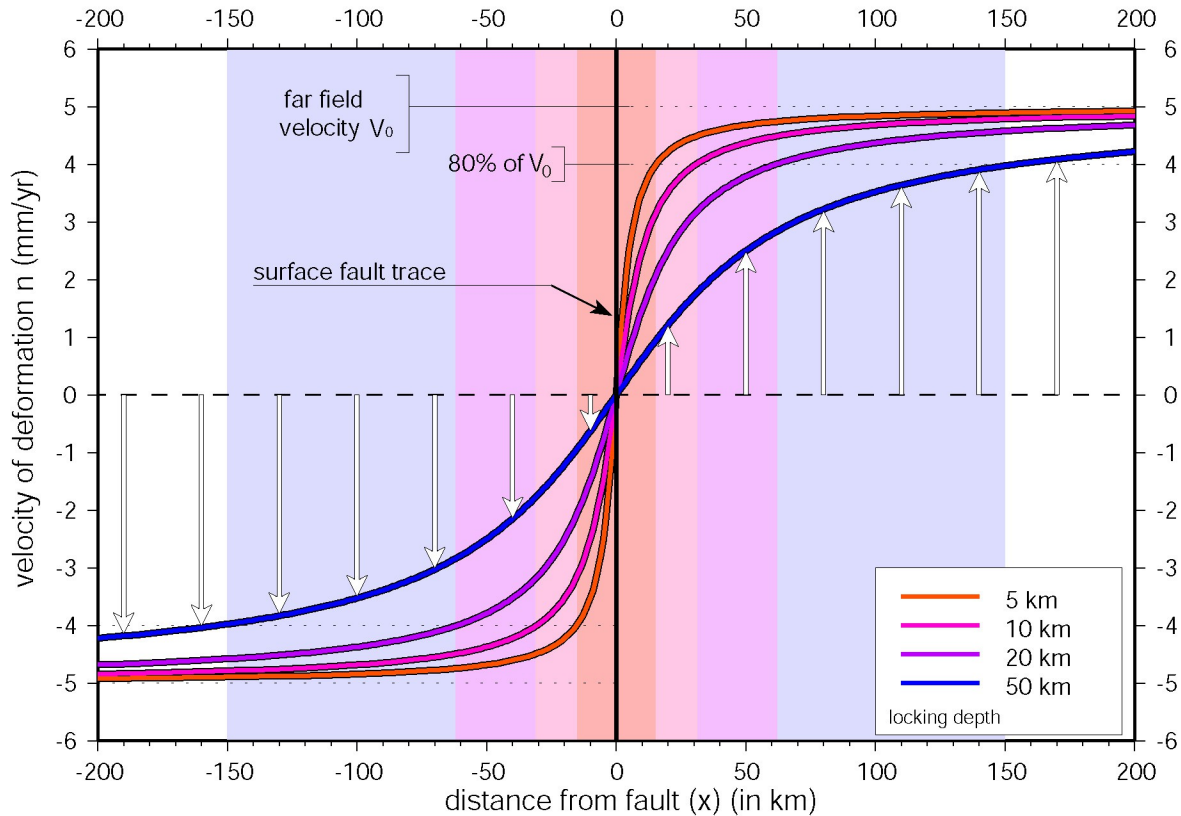
at the surface ($z=h$)

$$U_y = 2 \cdot V_0 / \Pi \arctang (x/h)$$

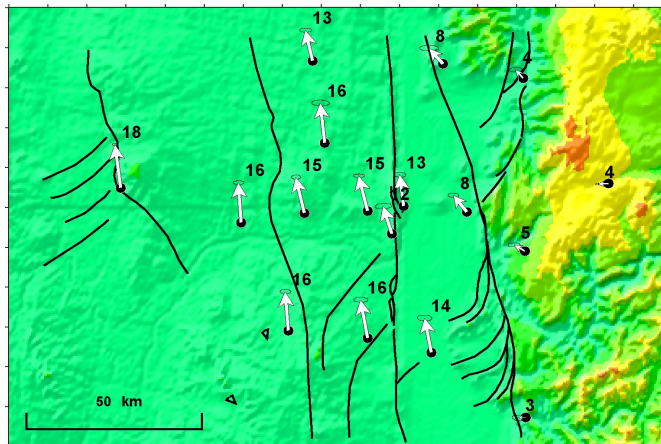
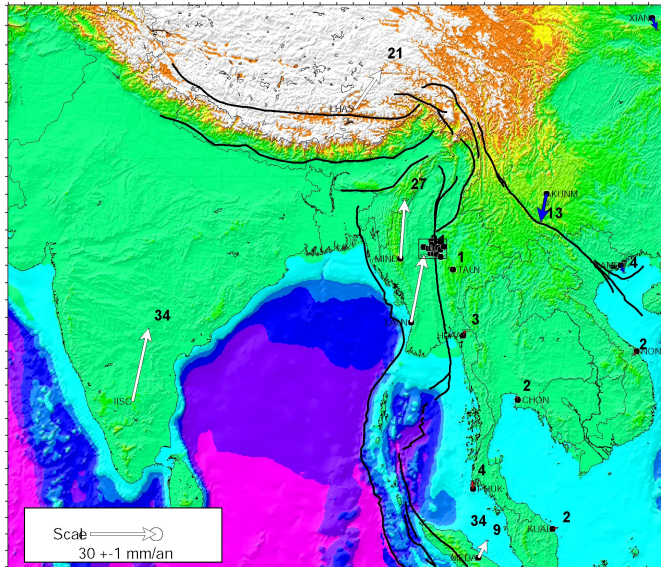


Arctang profiles

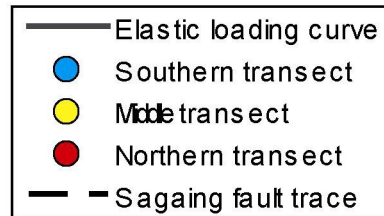
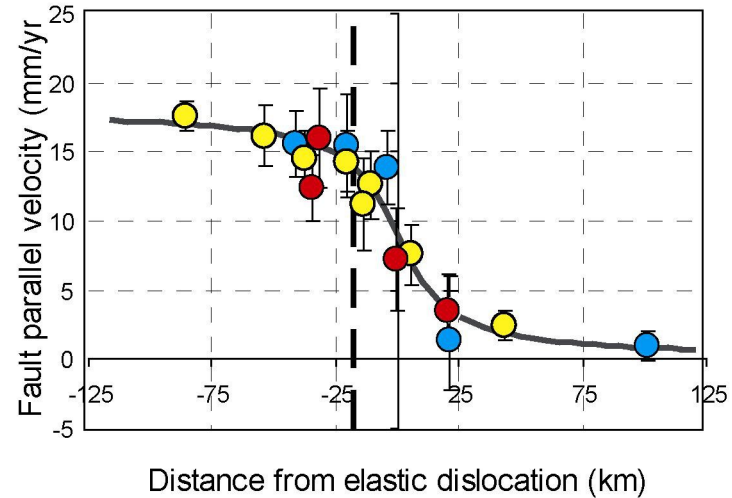
$$U_y = 2 \cdot V_0 / \pi \arctang (x/h)$$



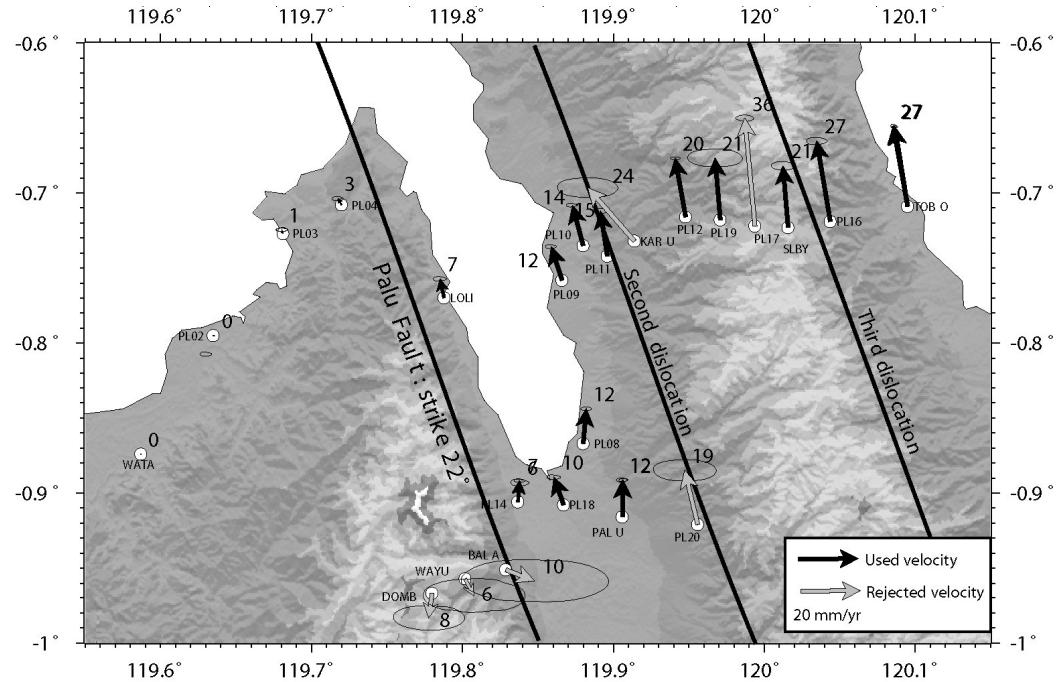
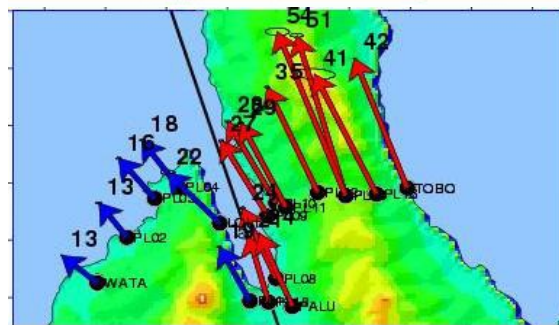
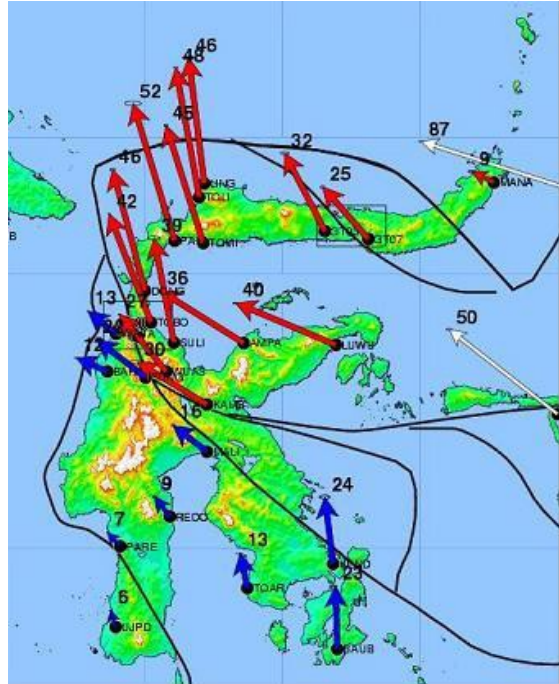
Sagaing Fault, Myanmar



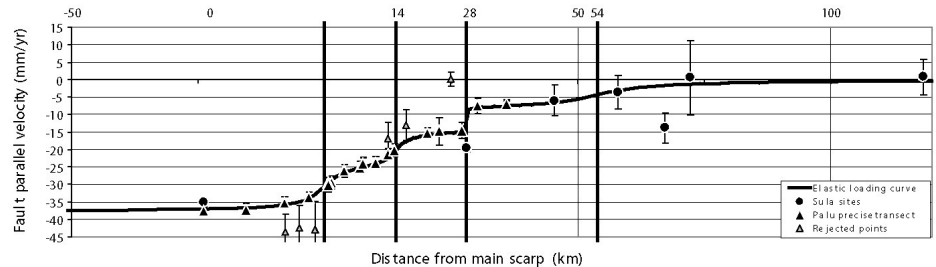
Offset fault/dislocation = 17 km
 Dislocation long. = 96.12° E
 Locking depth = 15.0 km
 Far field velocity = 18 mm/yr



Palu Fault, Sulawesi

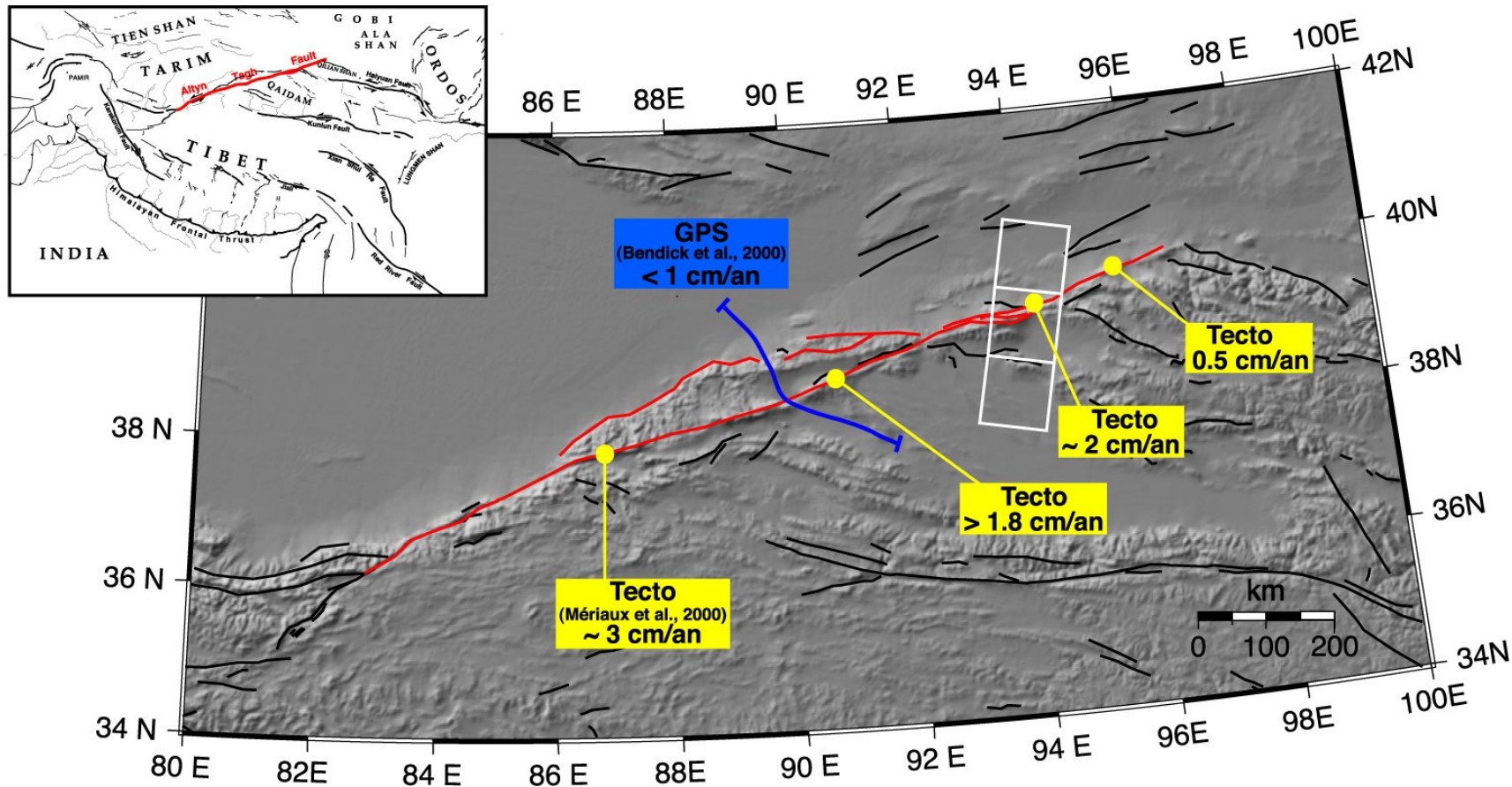


	MAIN F	2ND F	3RD F	4TH F
LOCKIN G D EPTH (km)=	3	2	0	8
VELOCITY (mm/yr)=	13	10	7	8



ME

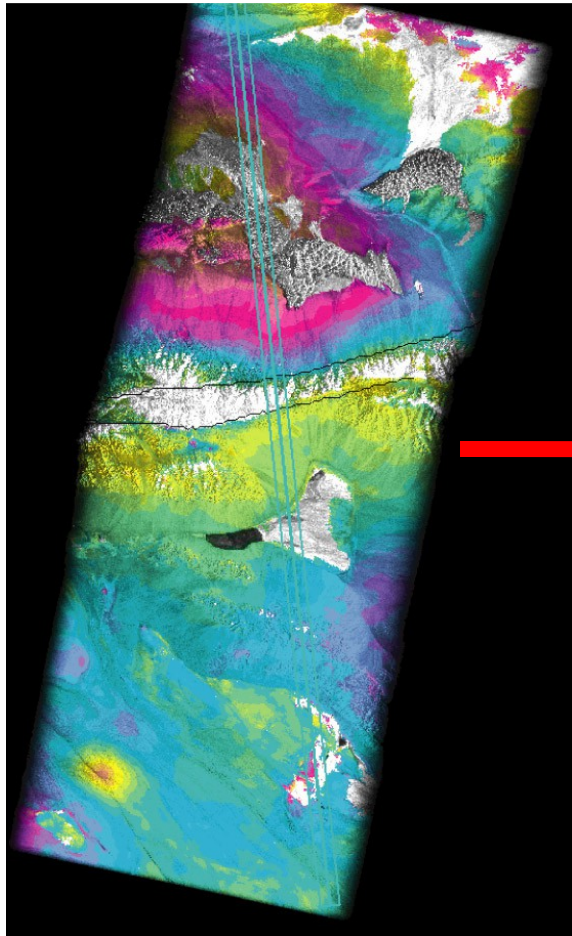
Altyn Tagh Fault, China



SEAMERGES GPS course
- Bangkok may 2004

Altyn Tagh Fault, China (INSAR)

Interferogram Nov. 1995/ Nov. 1999



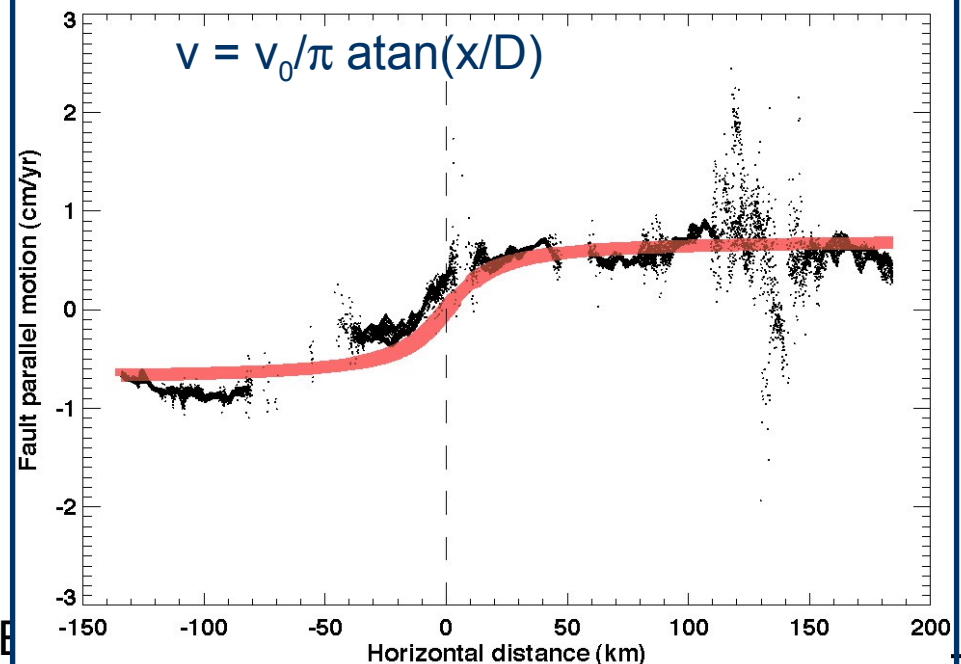
1 color cycle = 28 mm LOS displacement

- Bangkok may 2004

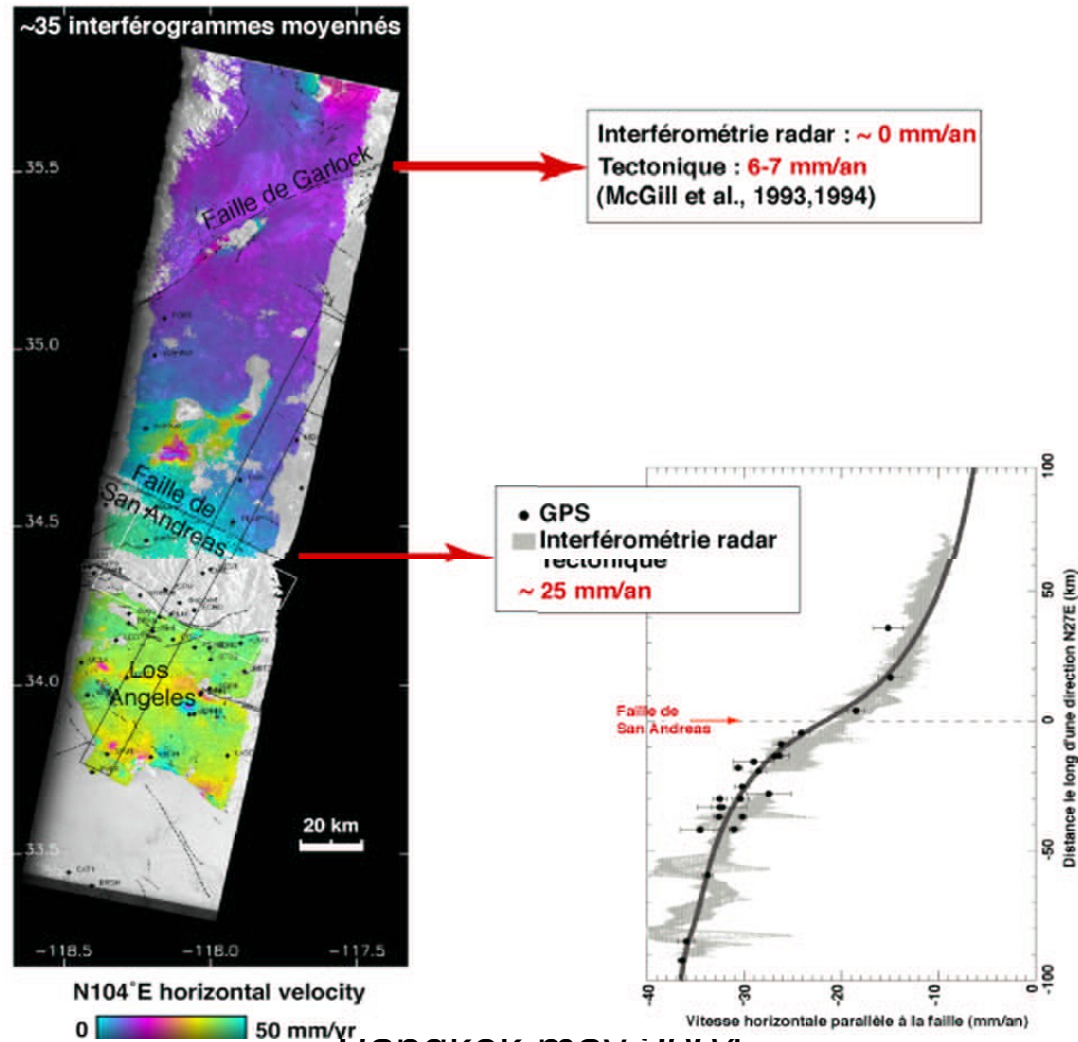
Fault-parallel velocity :

Slip rate $V_0 = 1.4$ cm/yr

Locking depth $D = 15$ km

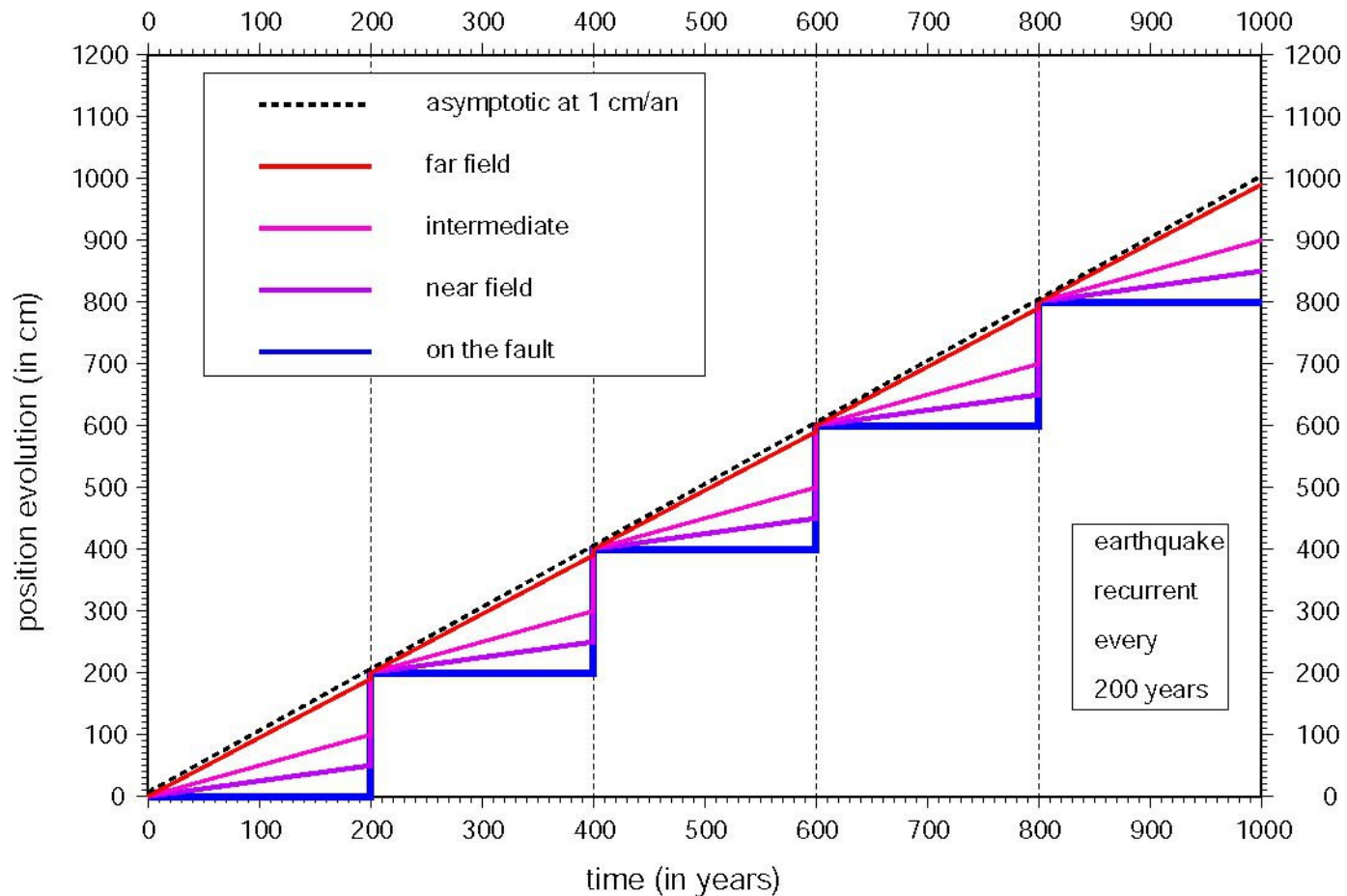


San Andreas Fault, USA (INSAR)

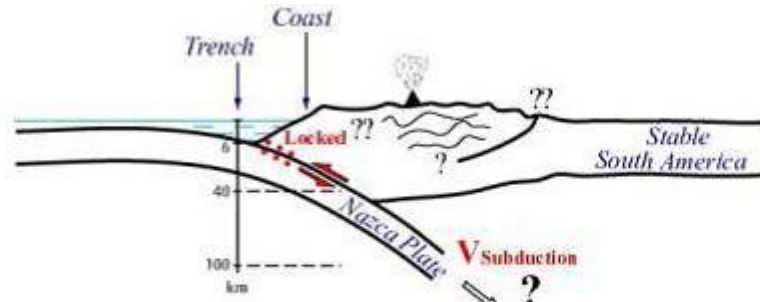


=> Cycle sismique

Time dependent station motion



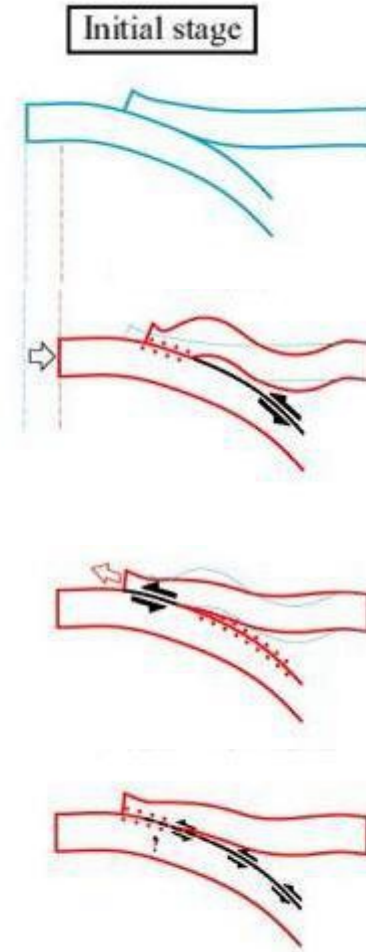
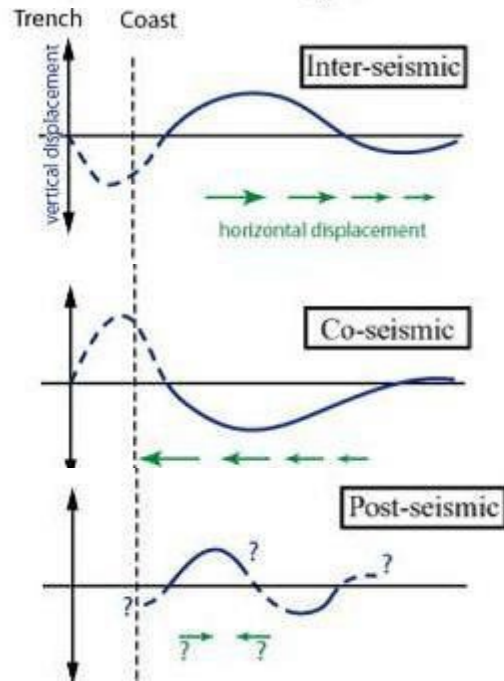
Cycle sismique en contexte de subduction



Géométrie du slab et physique de la friction

Modèle de rupture: répartition du glissement

Viscosité du manteau



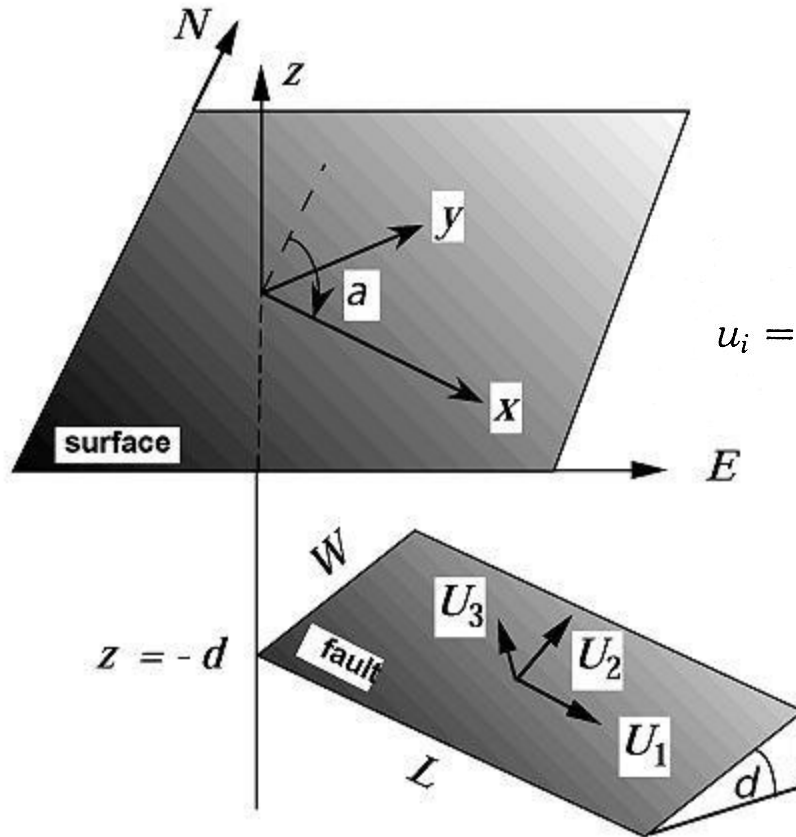
100^s years

seconds -> minutes

months- -> years

Elastic dislocation (Okada, 1985)

Surface deformation due to shear and tensile faults in a half space, BSSA vol75, n°4, 1135-1154, 1985.



The displacement field $u_i(x_1, x_2, x_3)$ due to a dislocation $\Delta u_j(\xi_1, \xi_2, \xi_3)$ across a surface Σ in an isotropic medium is given by :

$$u_i = \frac{1}{F} \int \int_{\Sigma} \Delta u_j \left[\lambda \delta_{jk} \frac{\partial u_i^n}{\partial \xi_n} + \mu \left(\frac{\partial u_i^j}{\partial \xi_k} + \frac{\partial u_i^k}{\partial \xi_j} \right) \right] \nu_k d\Sigma$$

Where δ_{jk} is the Kronecker delta, λ and μ are Lamé's parameters, ν_k is the direction cosine of the normal to the surface element $d\Sigma$.

u_i^j is the i^{th} component of the displacement at (x_1, x_2, x_3) due to the j^{th} direction point force of magnitude F at (ξ_1, ξ_2, ξ_3)

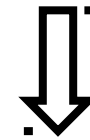
Couplage elastique subduction Sumatra



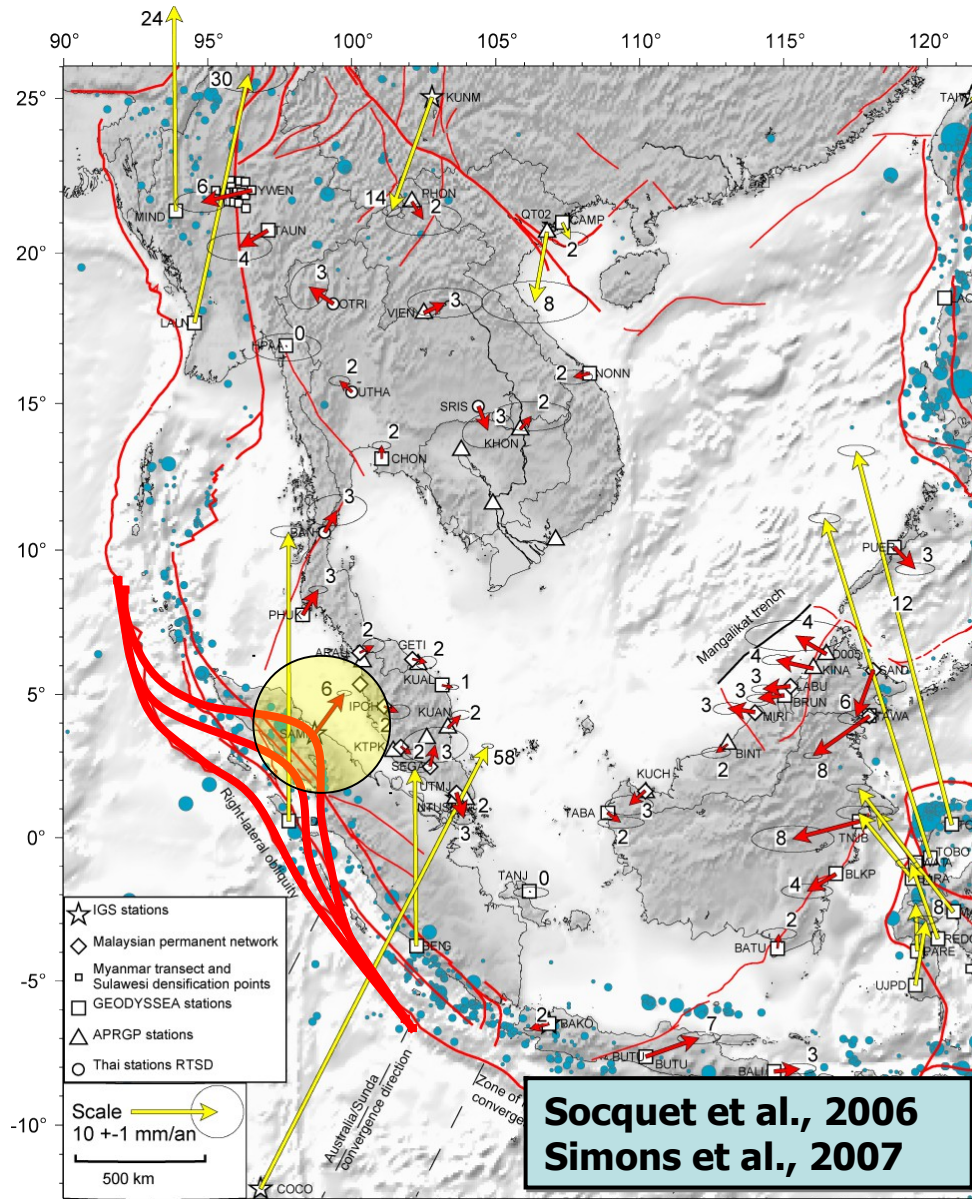
An earthquake in this region was inevitable

GEODYSSEA
+
SEAMERGES

~100 sites



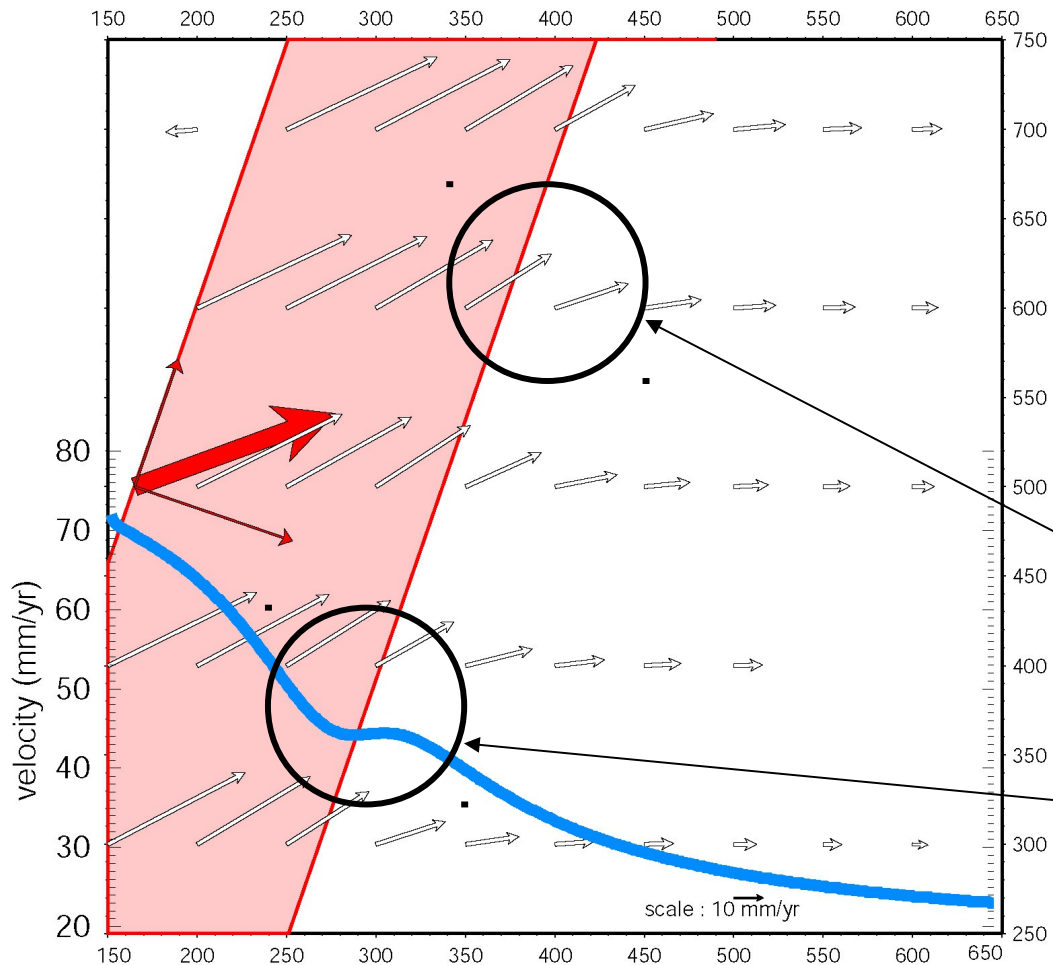
Deformation of Sundaland Platelet boundaries, in particular near **Sumatra** and Borneo



Subduction modeling

Oblique Subduction dip=20deg ld=60km V=72mm/yr

Velocity component // to convergence direction



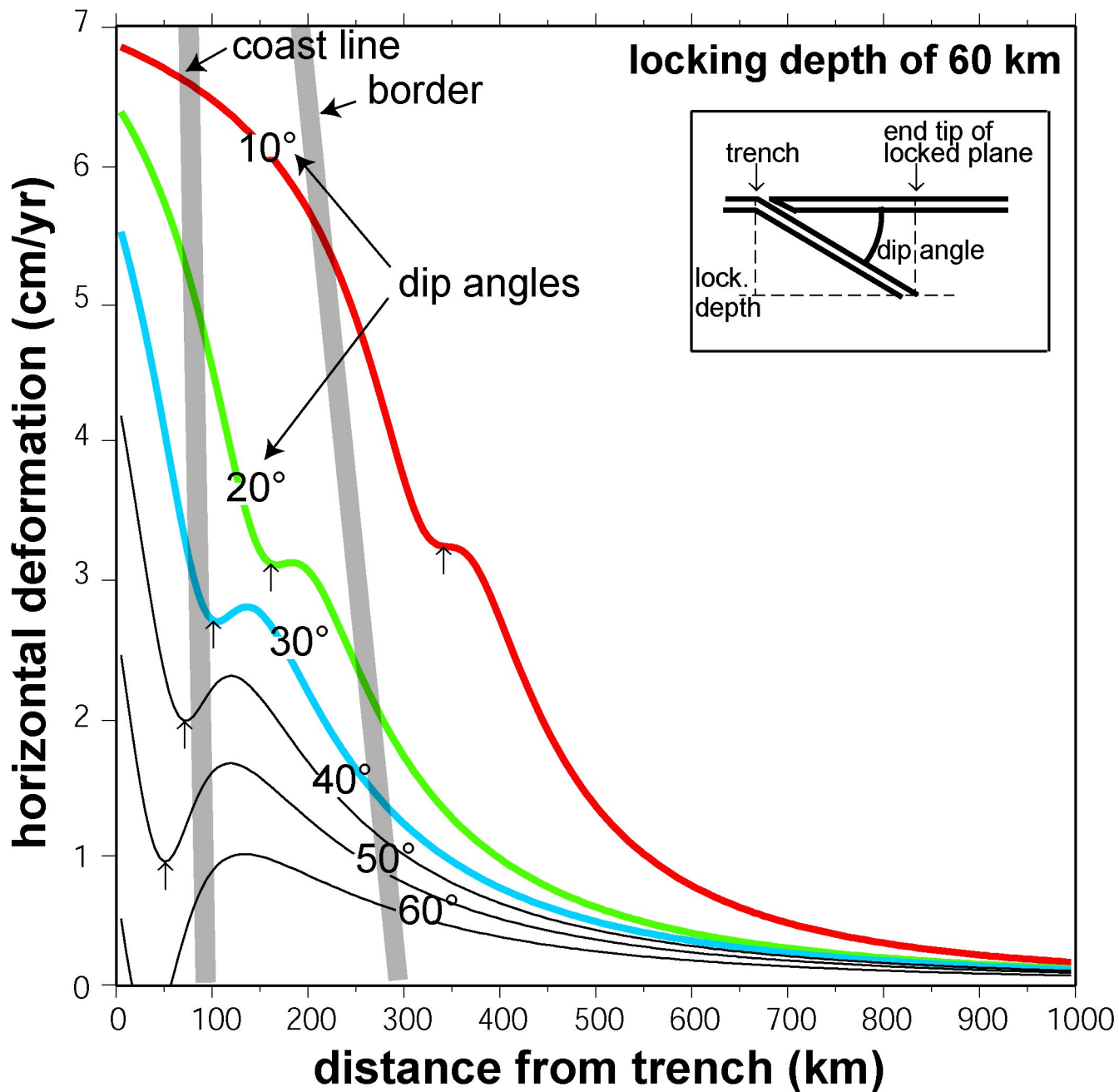
In the case of a subduction (dipping fault with downward slip) we use Okada's formulas.

We find a very large deformation area (> 500 km) because the dipping angle is only 22°

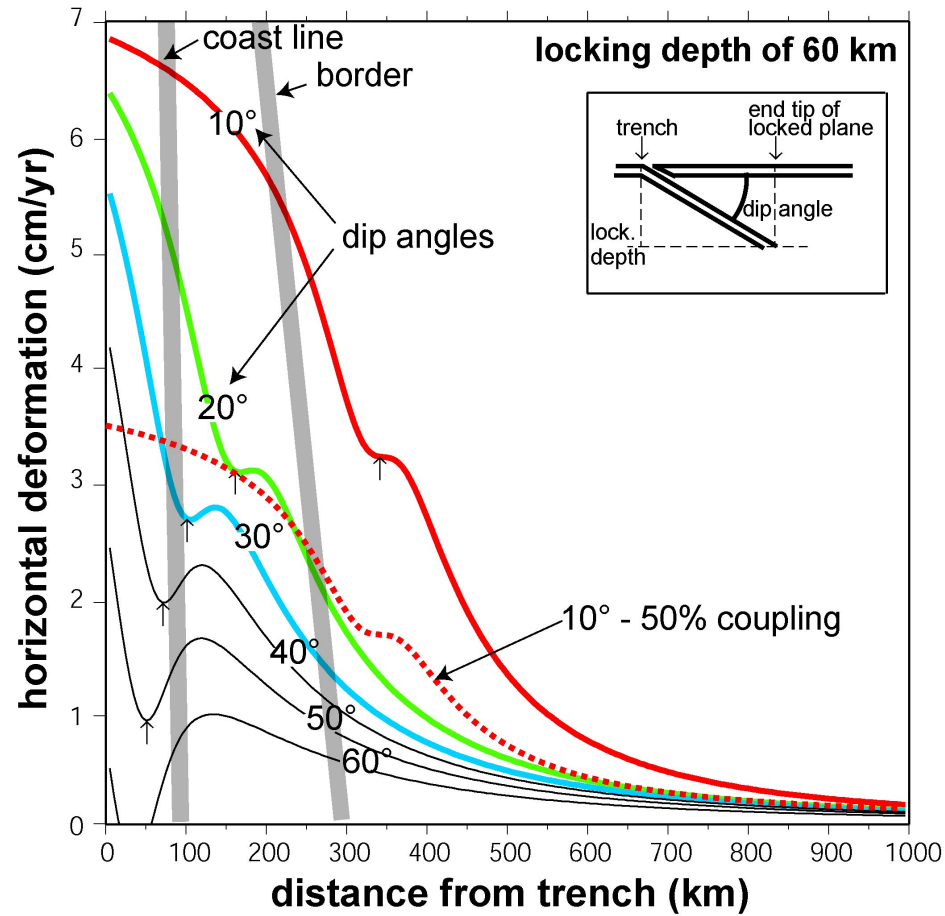
With oblique slip we predict the surface vector will start to rotate above the end-tip of the subduction plane

The profile of the velocity component // to the convergence shows a "plateau" at this location

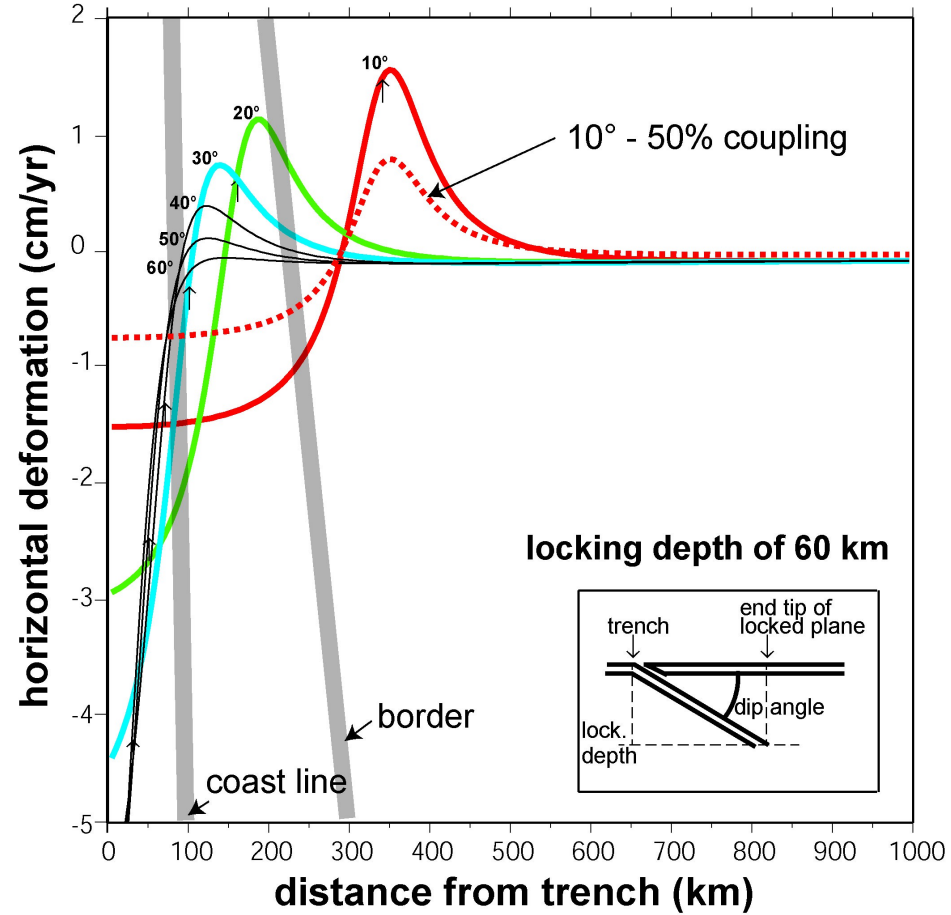
Subduction at 7 cm/yr



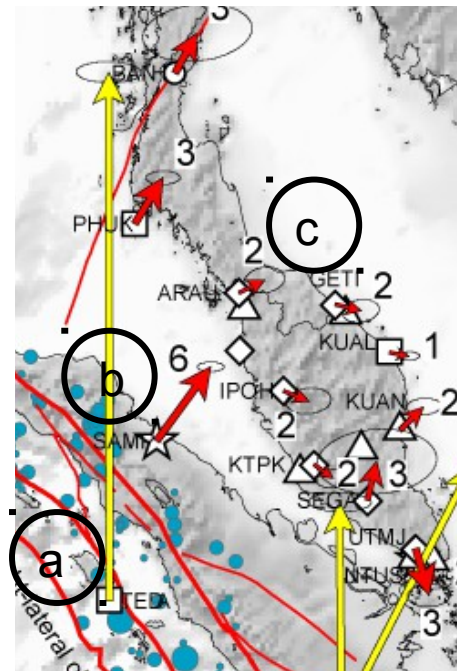
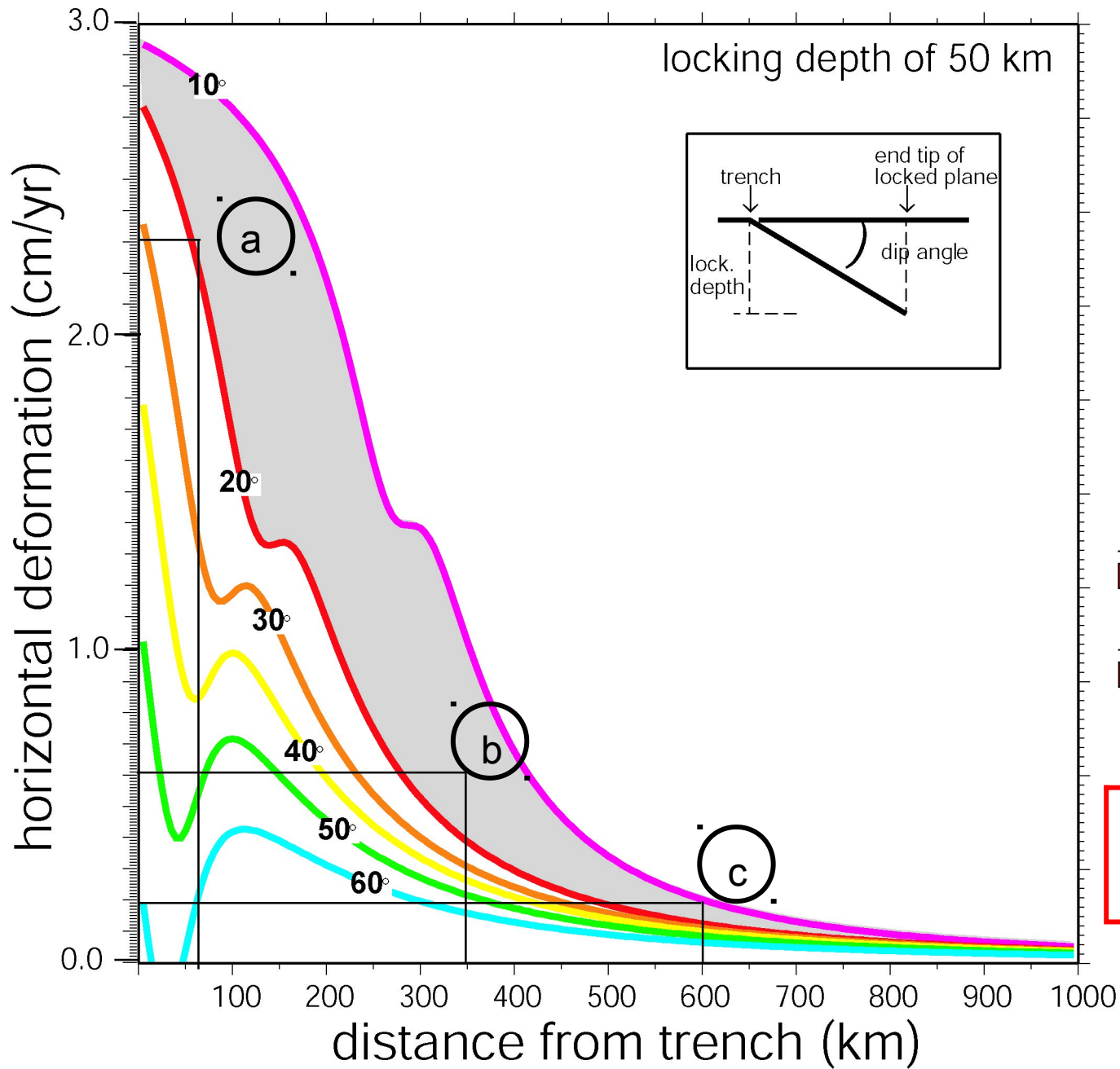
Subduction at 7 cm/yr



Subduction at 7 cm/yr



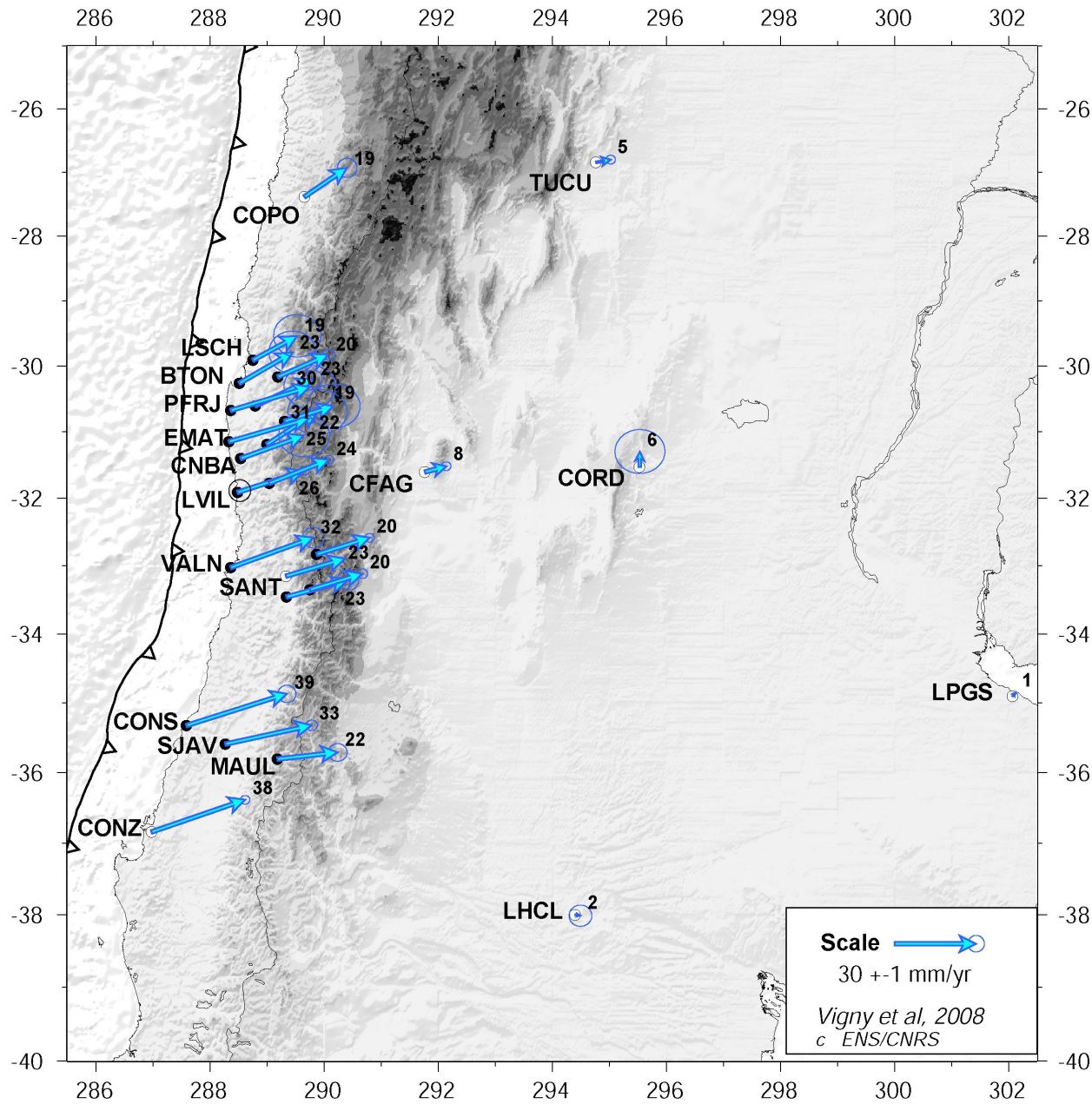
Subduction = 3 cm/yr



- Dip ~15°
- W ~200 km°

200km x 200km x 3m
= Mw 8 every 100 yr

GPS measures deformation of SAmerica

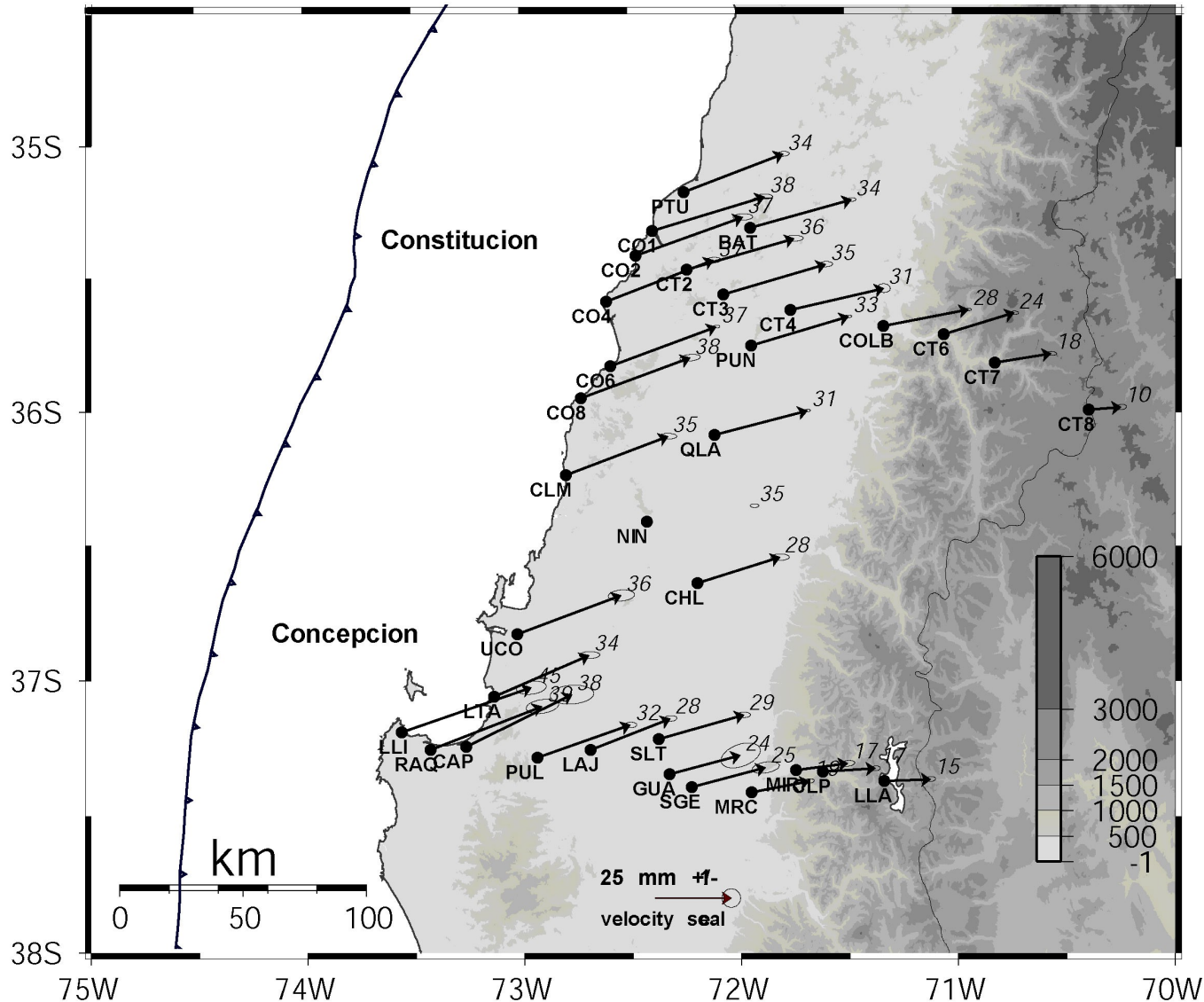


Deformation (elastic def. induced by coupling on the subduction) is visible in Chile

And

reaches far inland: TUCU (Tucuman) and CFAG (Coronel Fontana) in Argentina show deformation more than 400 km away from the trench

Zoom along high density profiles in Concepcion/Constitution area

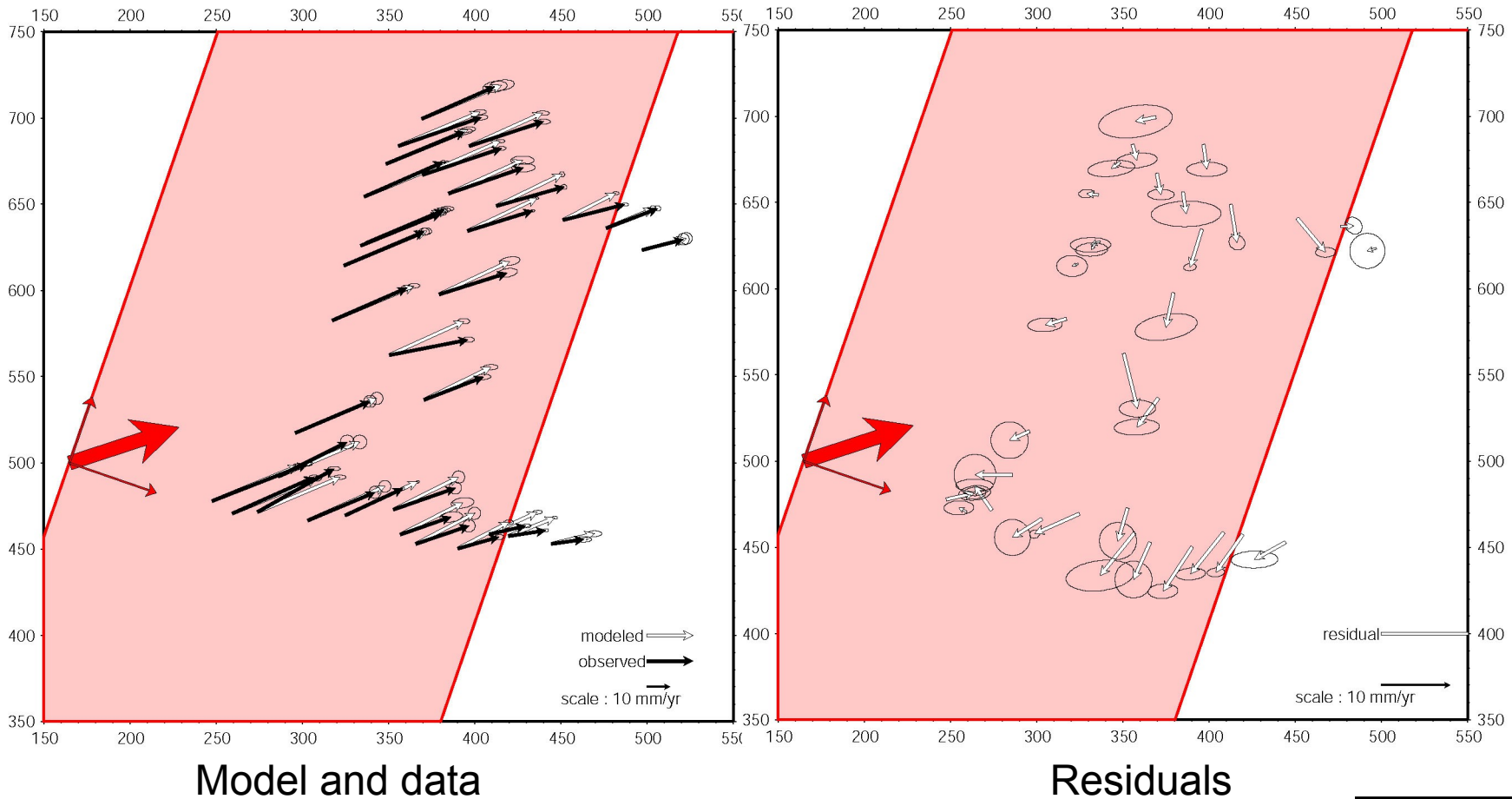


As expected from elastic coupling, velocities **decrease** Eastward (from 35-45 mm/yr along the coast to 10-15 mm/yr at the cordillera) and vector directions **rotate** from a direction // to plate convergence to East-West trending.

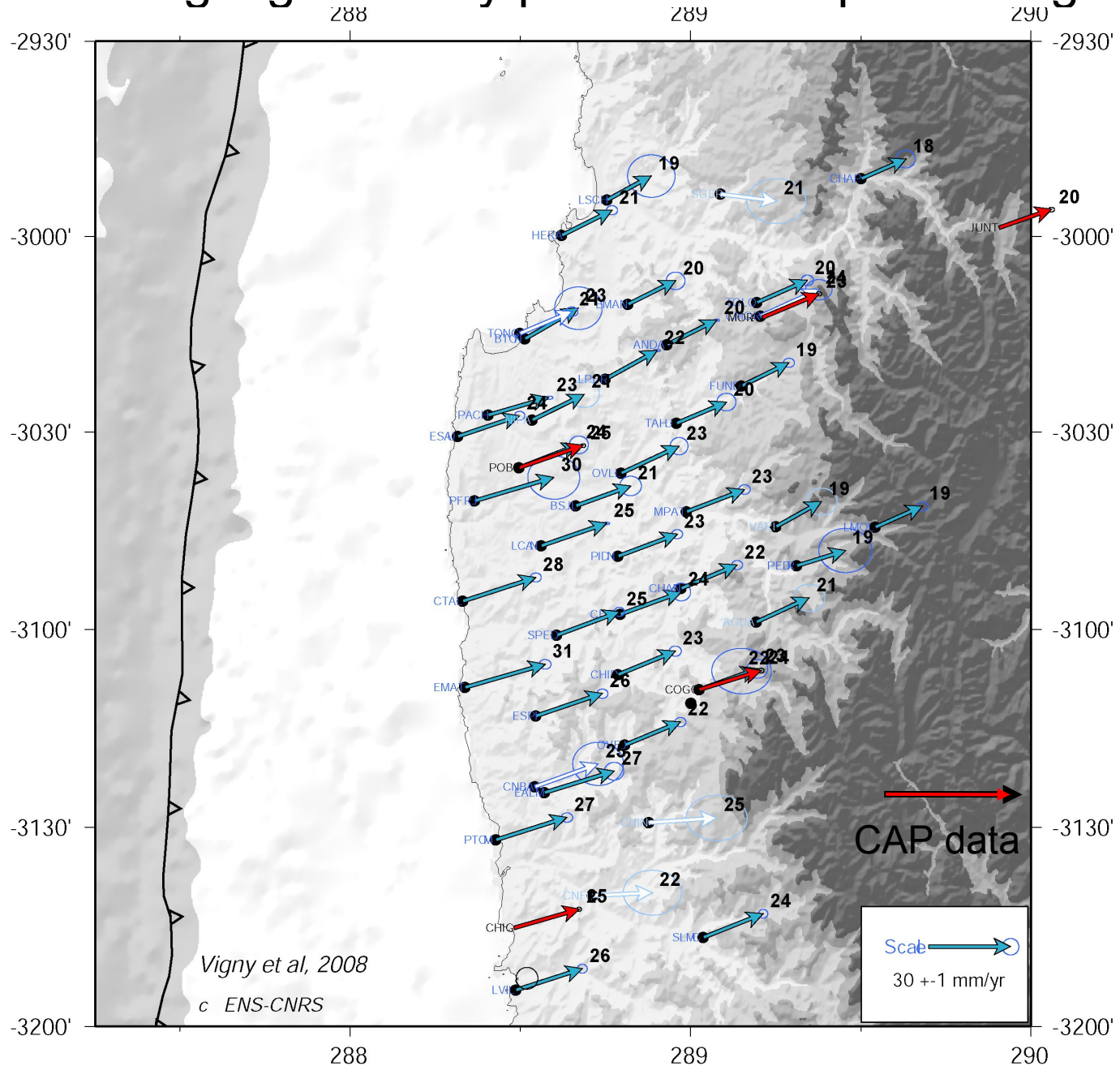
Subduction parameter adjustments

Oblique Subduction dip=13deg ld=60km V=50.2mm/yr N72

Oblique Subduction dip=13deg ld=60km V=50.2mm/yr N72



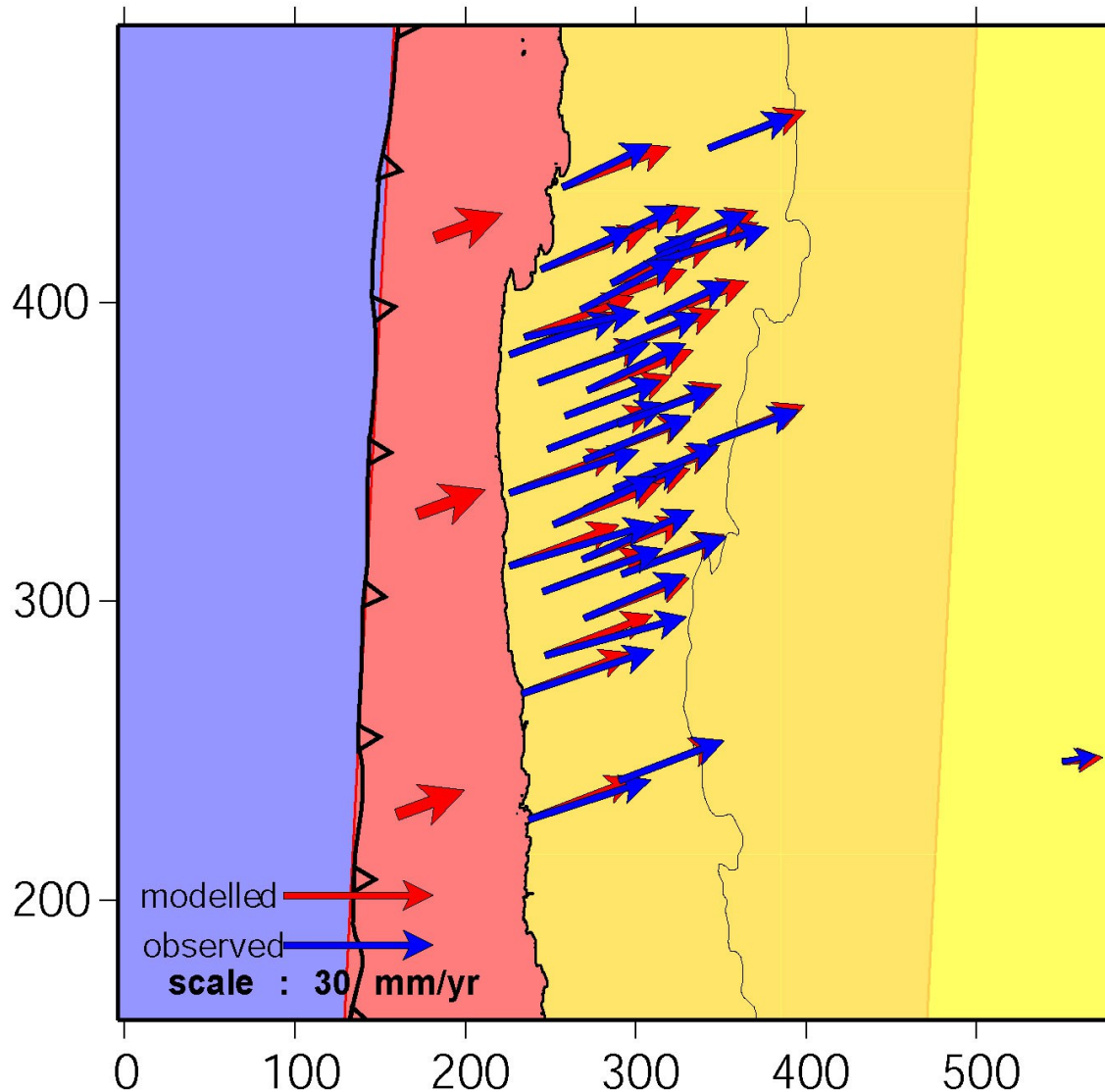
Zoom along high density profiles in Coquimbo region



Patial coupling model

observed/modelled Velocities

model parameters



Subduction strike: 5°N

Dislocation strike: 71°N

Locking Depth: 60 km

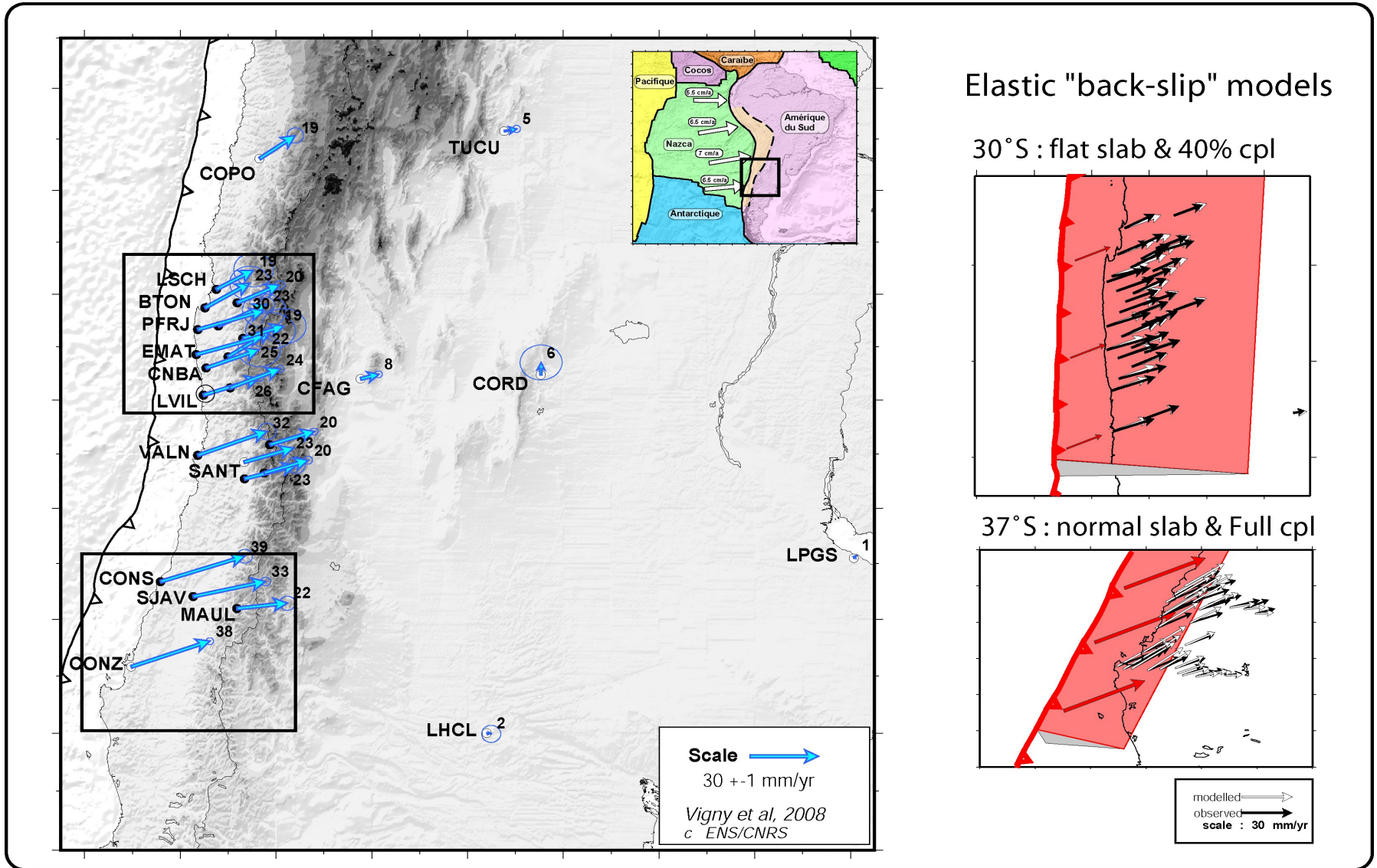
Plane Dip: 10°

Slip: 27 mm/yr

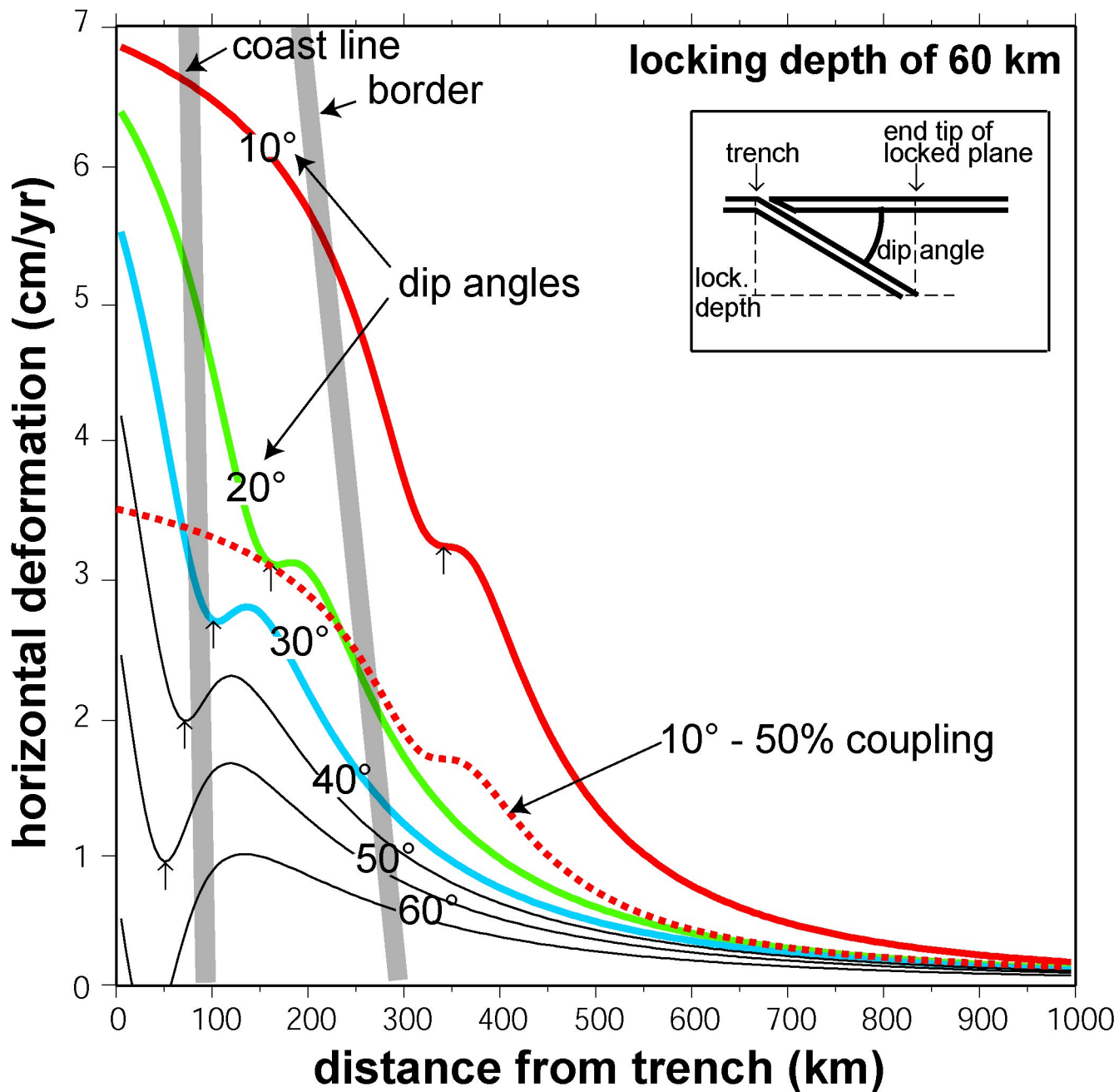
(41% coupling)

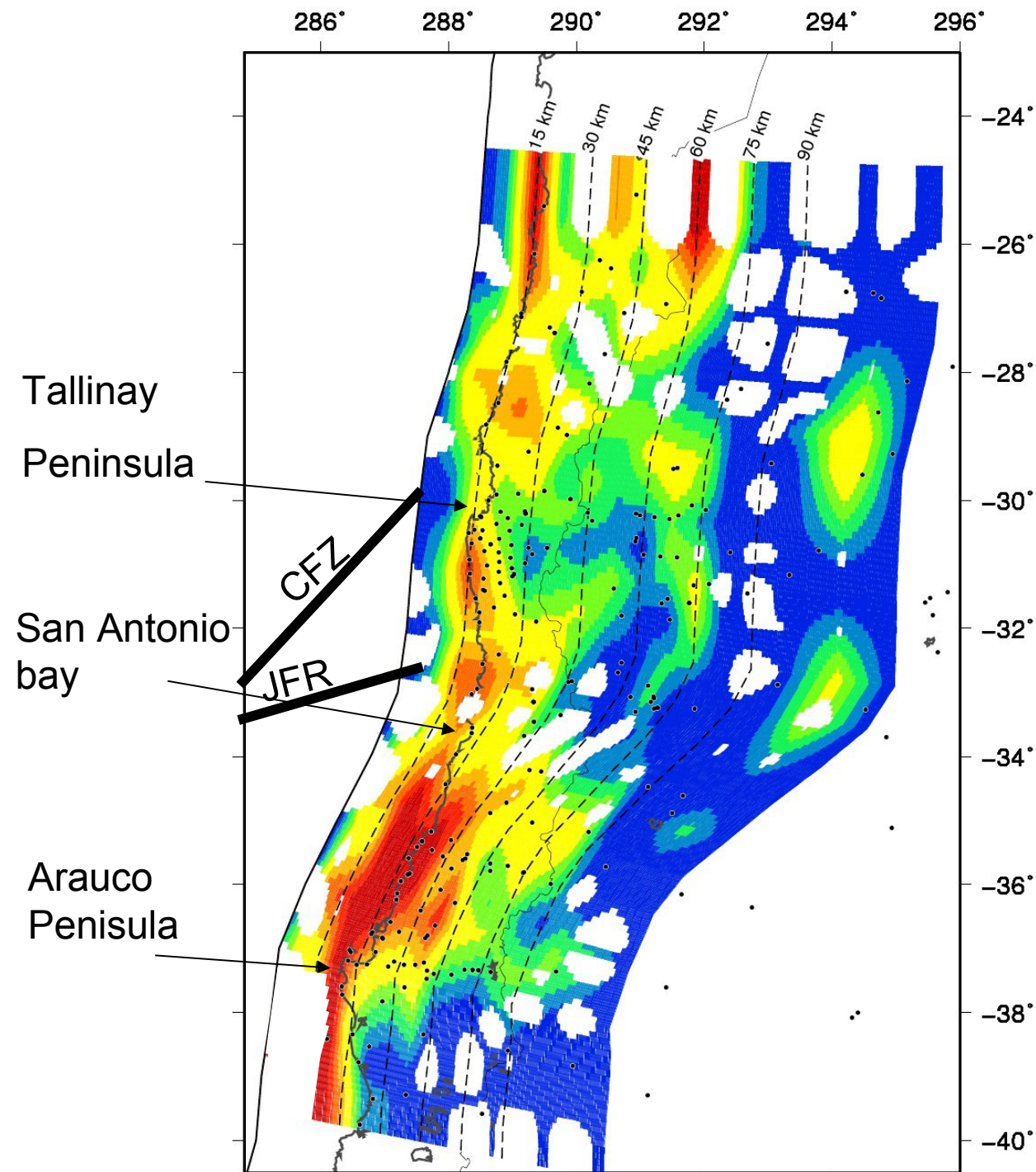
mean residual
2.6 mm/yr
over 34 points

Coupling is not always 100%



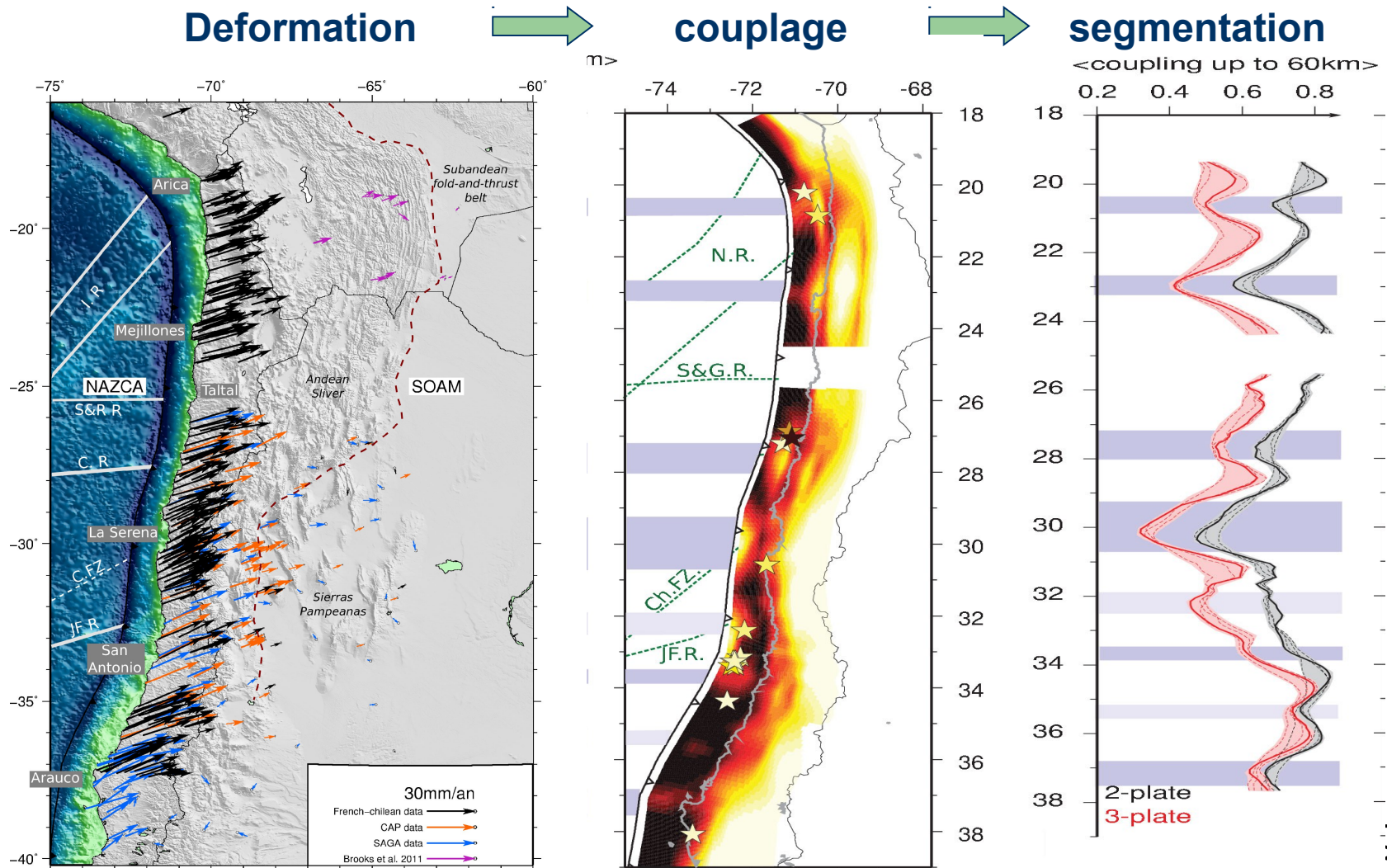
Subduction at 7 cm/yr





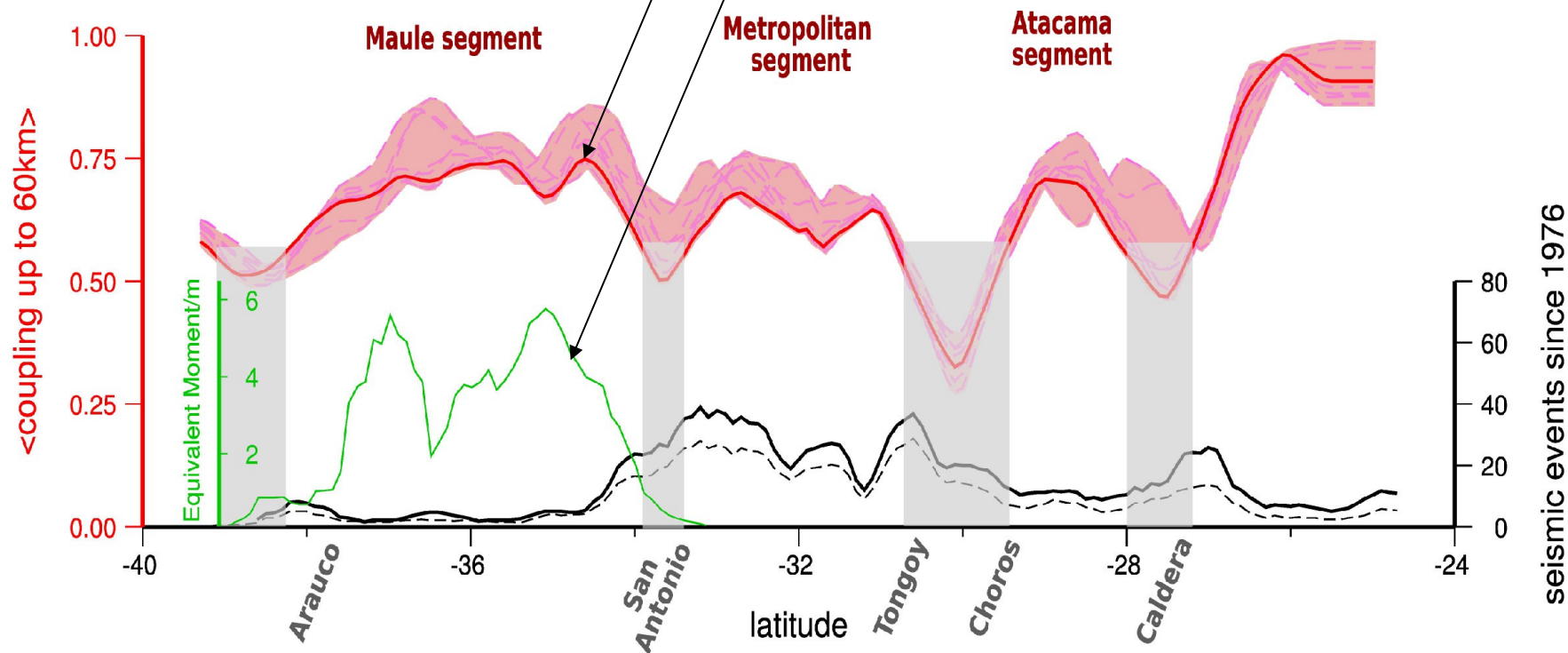
Inversion de la quantité de couplage sur des petits patchs sur la zone de subduction

25 years of GPS campaigns => coupling maps

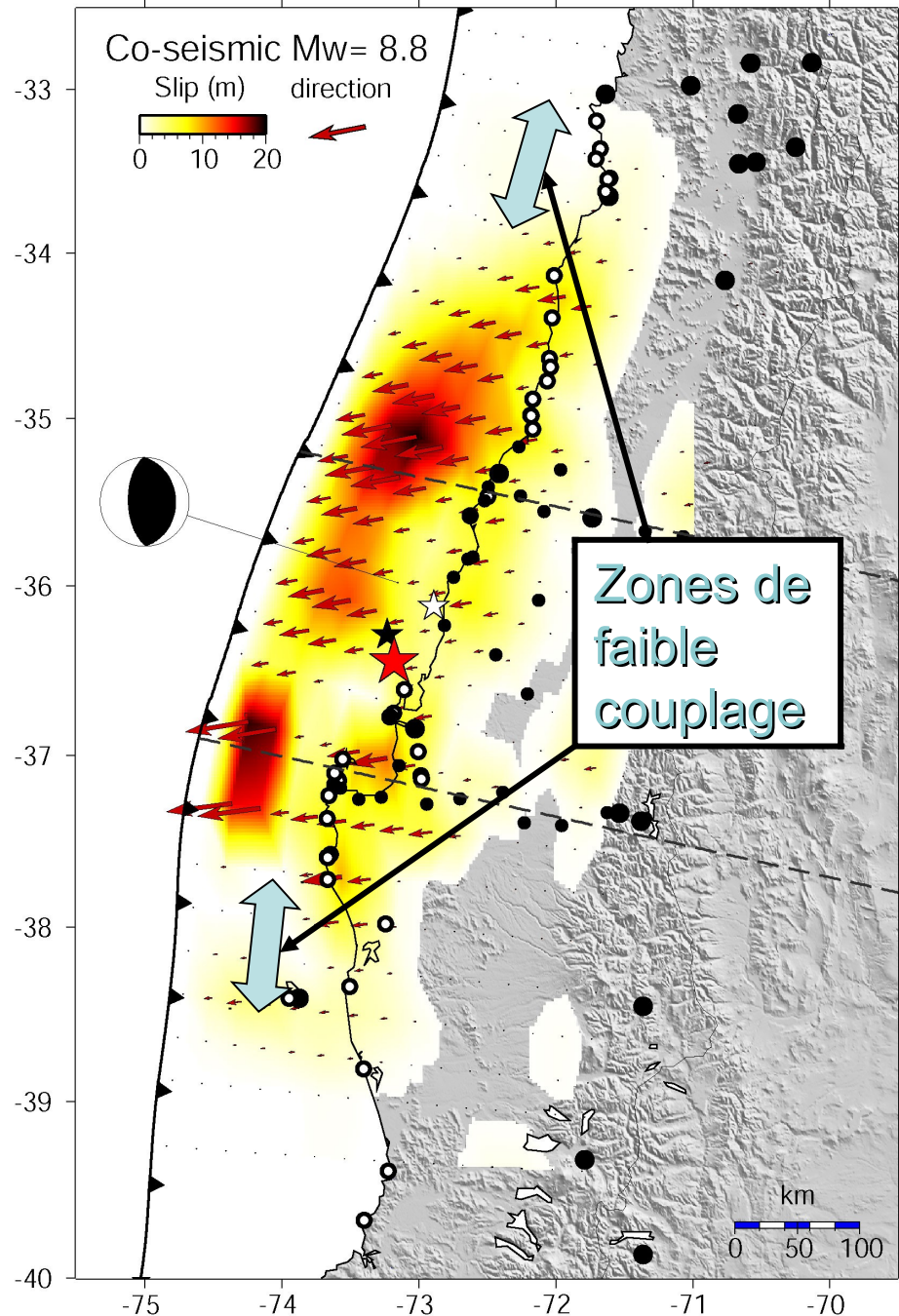
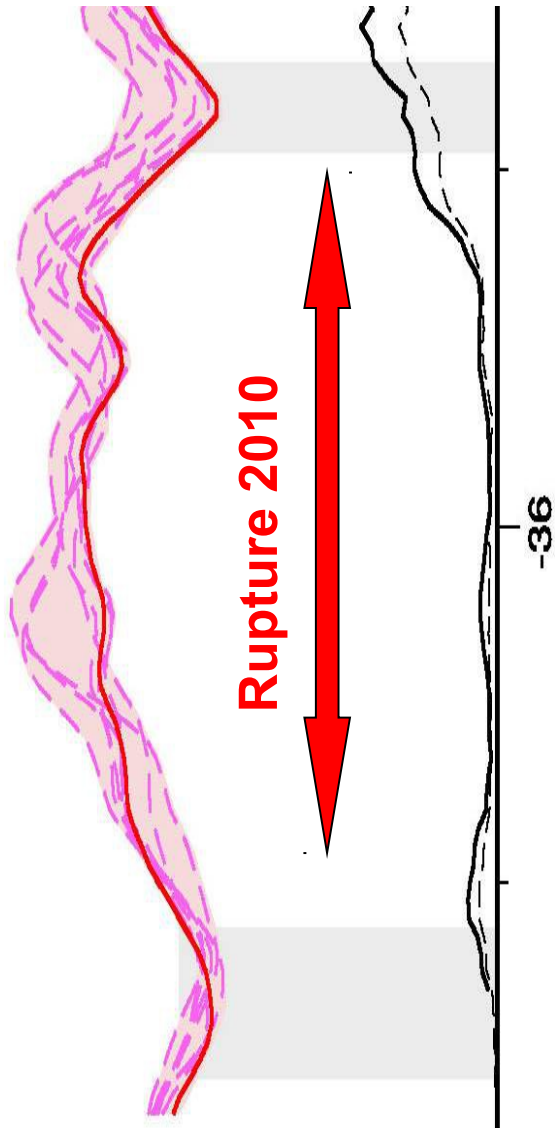


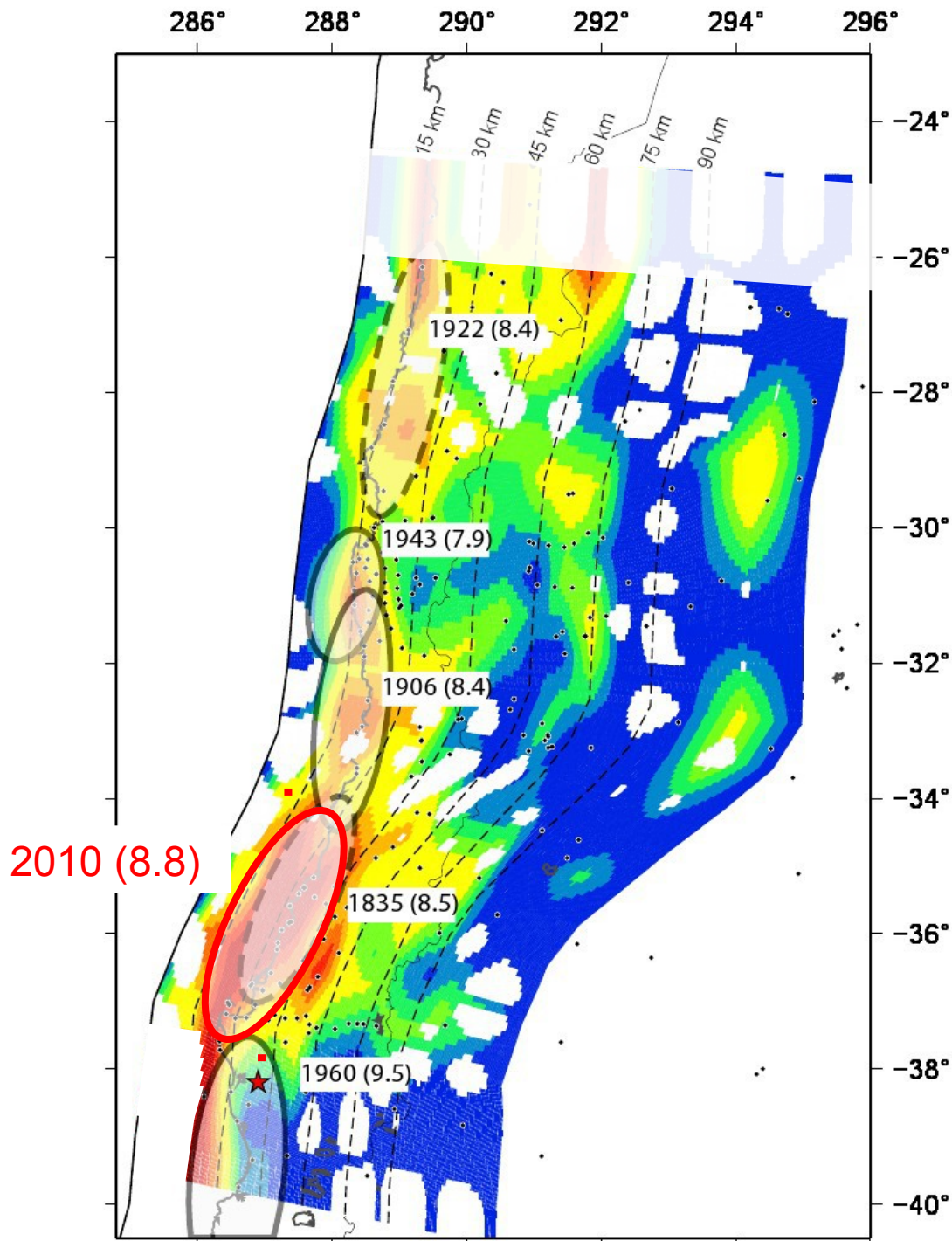
Quantité de couplage inter-sismique

Quantité de glissement co-sismique

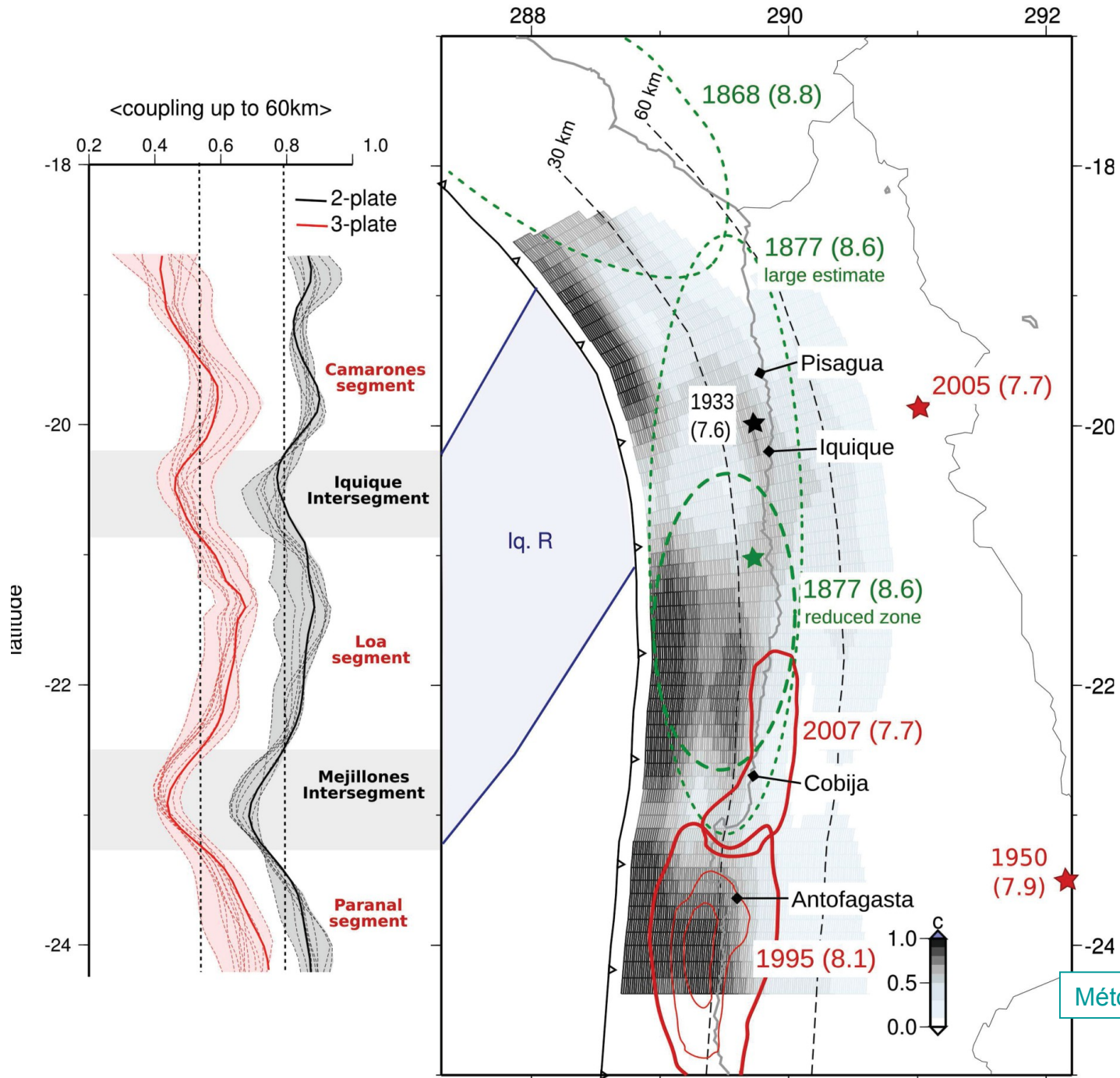


Maule segment





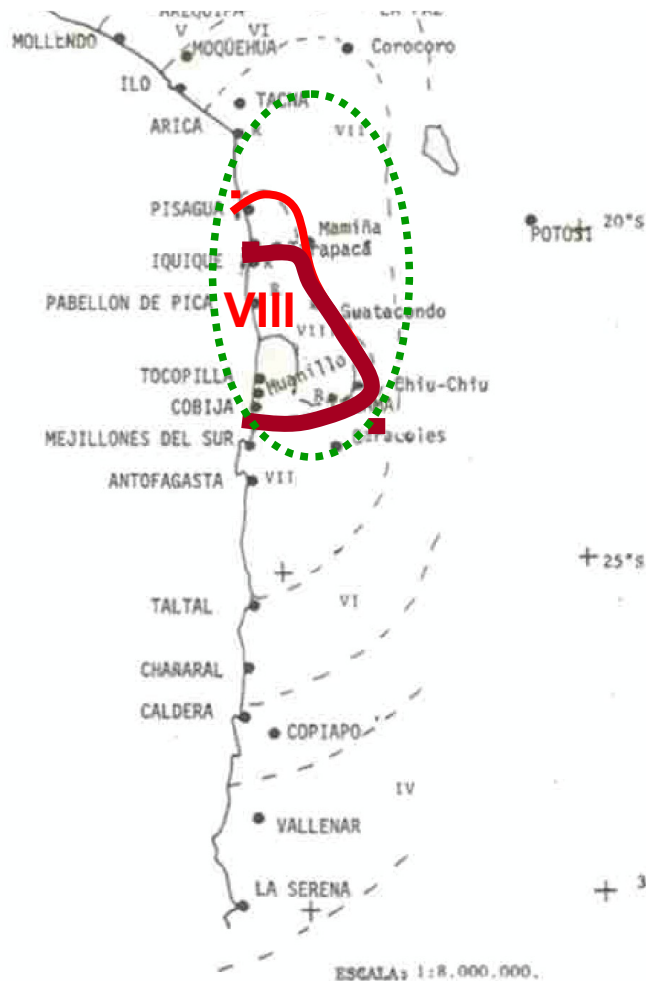
Corrélation
entre :
zones
couplées
aujourd'hui
et
ruptures
sismiques
historiques!



Kausel E.

Boletín de la Academia Chilena de Ciencias, 3–14, 1986.

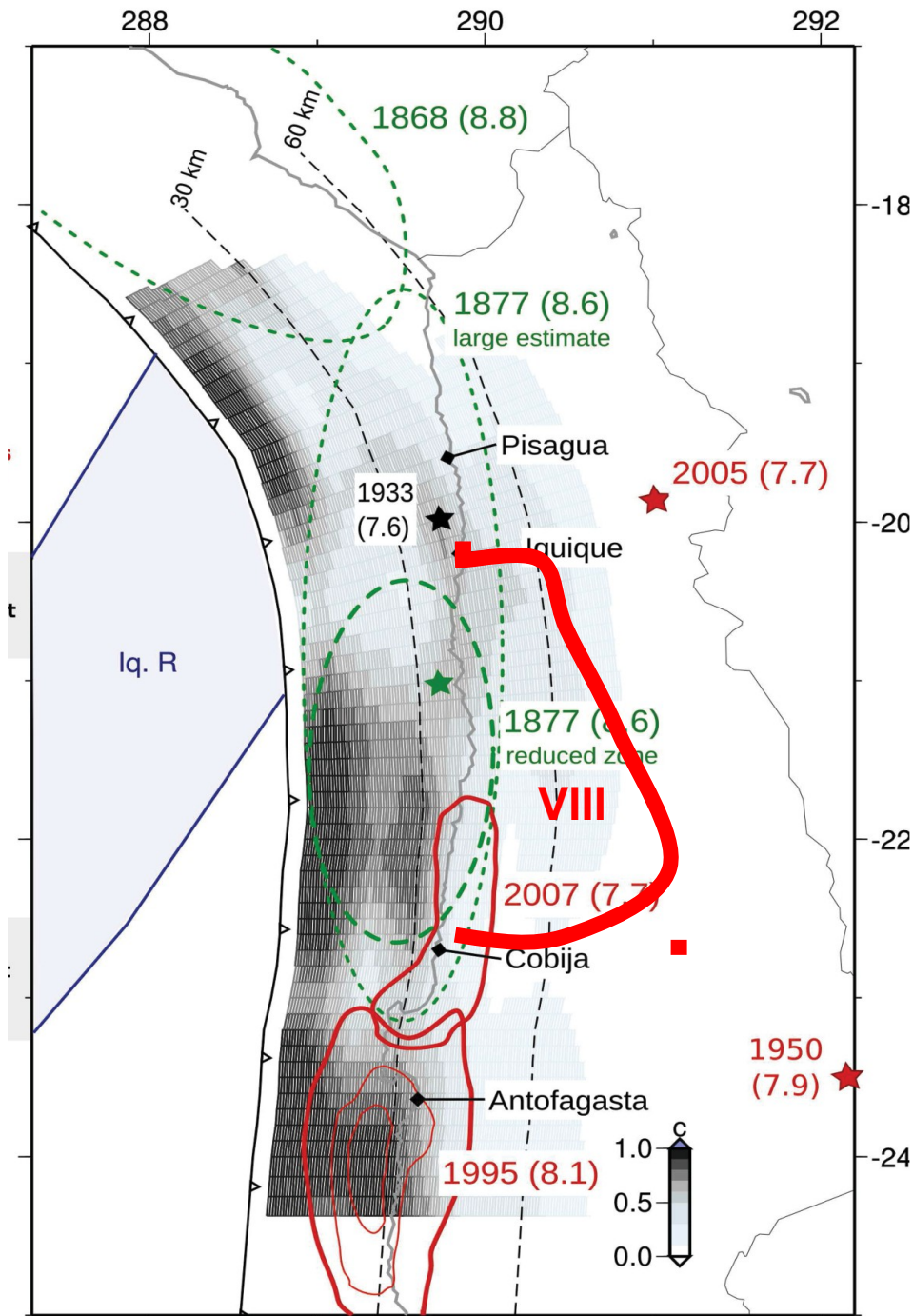
Los terremotos de agosto de 1868 y mayo de 1877 que afectaron el sur del Perú y norte de Chile.



De acuerdo con Vidal Gómez (1884), el corresponsal de El Comercio de Lima en Pisagua informó que él y otros observaron que “La tierra ha bajado considerablemente desde el terremoto del 9; hoy (el mar) baña en las altas mareas terrenos y rocas que siempre han estado secos y con algunos edificios”.

Esta observación es muy interesante pues permite suponer un hundimiento de la costa en Pisagua, lo que nos ha hecho incluir a este punto dentro de la zona epicentral a pesar de que la intensidad parecería no haber alcanzado el grado VIII. El mismo corresponsal informa de un “sorprendente fenómeno físico que ha preocupado a muchos y que tiene alarmados a todos”. Las personas que presenciaron este suceso dicen que en Pisagua “como a 50

Fig. 2. Sismo del 9 de mayo de 1877. $M = 8 \frac{1}{4}$; $M_t = 9$; $M_w = 8,9$. Clave igual a Fig. 1.



Donc deux scenarios pour le big one attendu :

1. une « répétition » d'un très grand séisme (500 km de rupture d'Arica à Antofagasta , imminente
2. un séisme rompant le segment actuellement couplé du « Loa »
 - seulement 200 km de long
 - plus petit si aujourd'hui
 - magnitude proche de 9 si dans 100 ans
3. Ou ?

Métois et al., *GJI*, 2013