Subduction Science: Discussion on seismic coupling

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Outline

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1. Early Observations
2. Early Interpretations
3. Current Models of Interseismic deformation

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3. Current Models of Interseismic deformation
4. Plate Model

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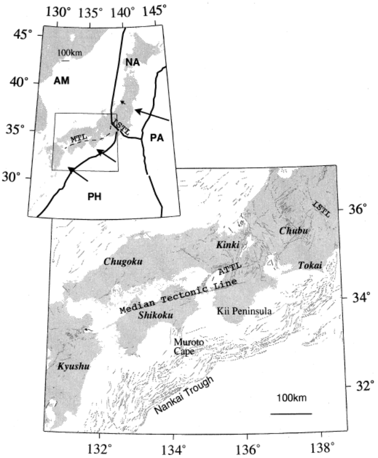
Early observations

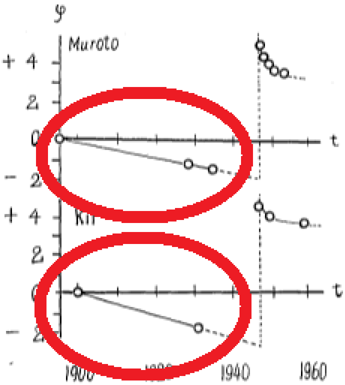
Since 1880 the development of geodetic survey allowed detailed observations based on:

- Land survey, repeating precise first order levelling.
- Mareographical observations.
- Geophomorgical studies on the sea shore and marine terraces.



Observations in Japan

Recognizing three main regimes (prior to Plate Tectonics):



Tilt during 60 yrs

Steady Pre-seismic

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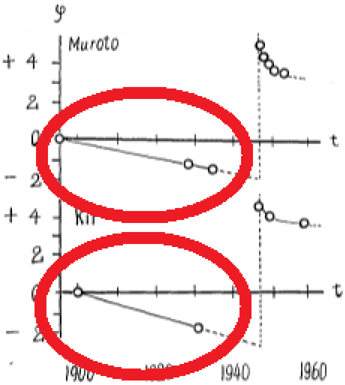

Steady Pre-seismic

Tilt during 60 yrs
(From: Tsuboi 1932, Imamura, 1932, Miyabe 1942, Okada 1961, Fitch and Scholz, 1971; Kanamori, 1973)

Observations in Japan

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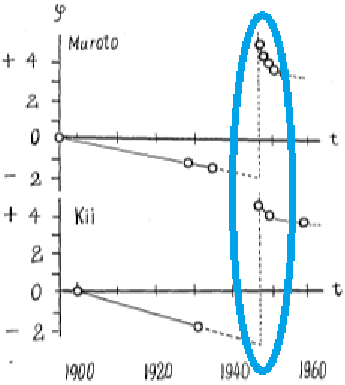


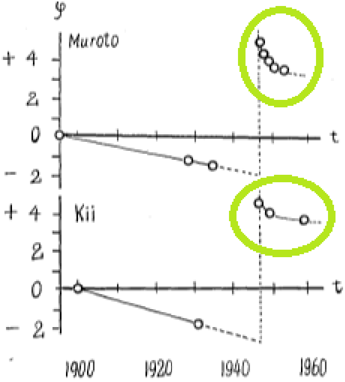
Tilt during 60 yrs

Strong Co-seismic

Earthquakes in
Tanankai (1944, M=8.0)
Nankaido (1946, M=8.2)

Observations in Japan

Recognizing three main regimes:

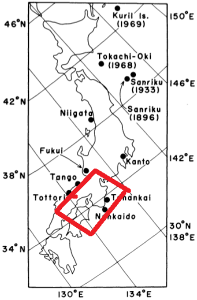


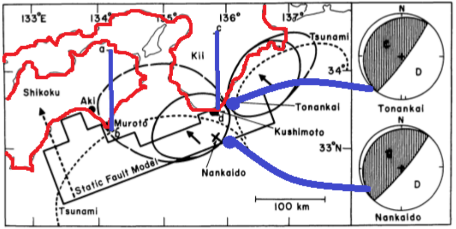
Tilt during 60 yrs

Short Post-seismic

Observations in Japan

Map of Geodetic observations and profiles



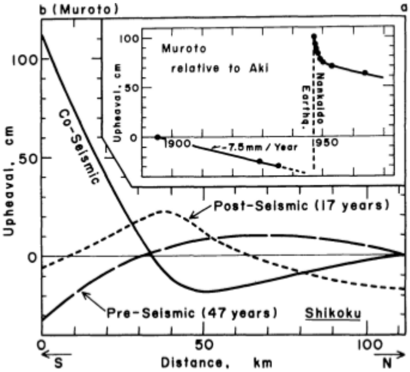


Two Profiles: a-b , and c-d

Observations in Japan

Profile: a-b

Vertical displacement on land

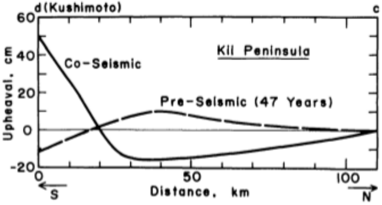


Pre-Seismic has opposite displacement than Co-Seismic

Observations in Japan

Profile: c-d

Vertical displacement on land



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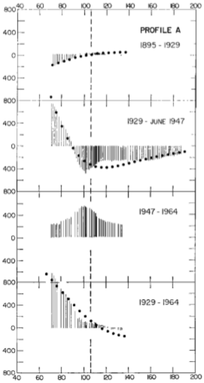
Observations in Japan: Summary



Pre-seismic

Co-seismic

Post-seismic

Co-seismic +
Post-seismic

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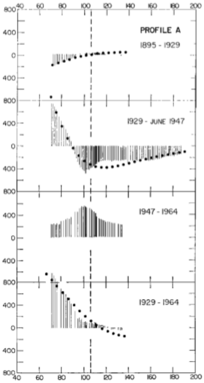

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(1) Pre-seismic is the inverse of Post-seismic + Co-seismic

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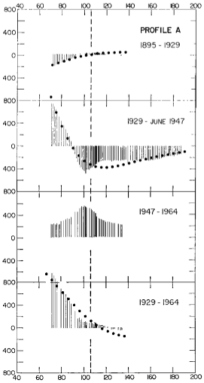

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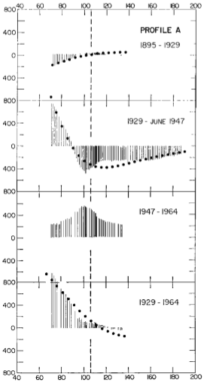

Pre-seismic

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Post-seismic

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(1) Pre-seismic is the inverse of Post-seismic + Co-seismic
(2) Pre-seismic displ. rate × Recurrence time ∼ Co-seismic displ.
(3) Rebound theory: Pre-seismic = Load , Co-seismic = Unload

Outline

Plate Tectonic

Already in 1910, Reid proposed the **rebound theory**, but required the source of energy to load the crust.

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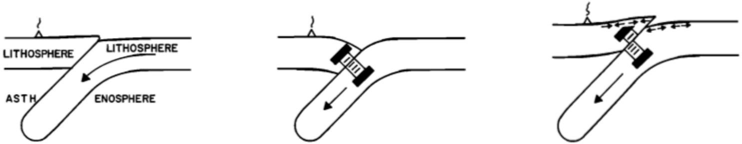


(a) Steady-state, (b) Inter-seismic , (c) Co-seismic

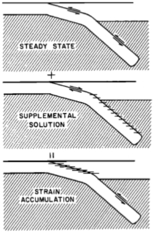
(From Fitch and Scholz, 1971)

Outline

Physical model: Back-Slip Model: widely used

(Savage J. C., 1983, JGR, 88, 4984-4996)

Main principle:



Steady state (no net displacement)

+ Suplemental Solution (Coseismic^{-1})

= Interseismic

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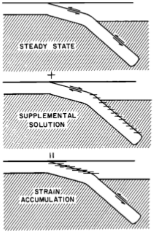

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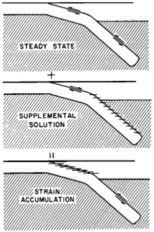

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Is this correct ?

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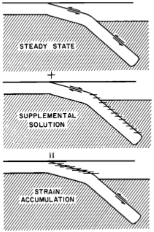

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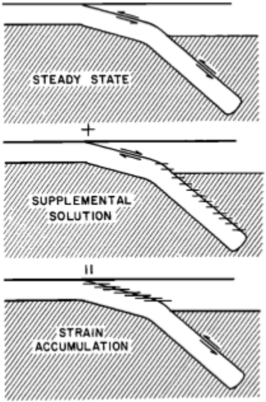
Is this correct ? **We don't think so!**

Why not?

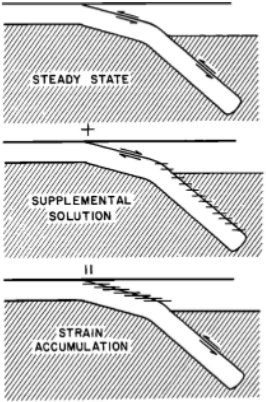


Steady state → net displacement !

Suplemental Solution is unrealistic

if plate subducts,
requires slip in lower interface,
and is not considered.

Why not?



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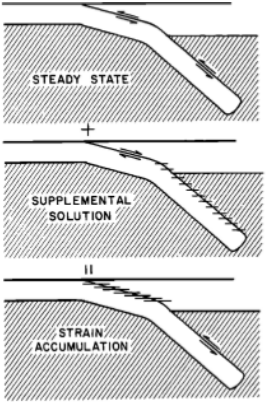
Better Solution:

Why not?



Steady state → net displacement !

Suplemental Solution is unrealistic

if plate subducts,
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and is not considered.

Better Solution: "Plate Model"

Outline

Sieh et al 1999

Crustal deformation at the Sumatran Subduction Zone revealed by coral rings, GRL 1999

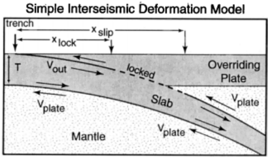


Figure 4. Sketch showing the parameters of an idealized model of interseismic deformation at a subduction zone.

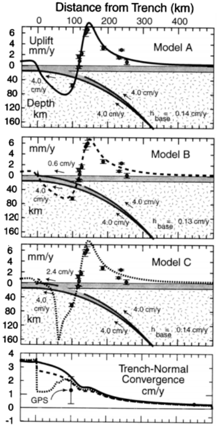
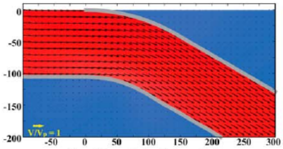


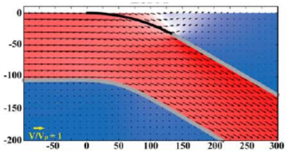
Figure 5. Cross-sections, showing the coral uplift rates (dots), slab slip extent (red lines) and predicted uplift rates (curves) for three deformation models. (Bottom) GPS summary datum (dot) and the predicted rates of convergence (curves).

Kanda & Simons 2010, Elastic Plate Model

Elastic Subducting Plate Model (ESPM)
(Kanda and Simons, 2010)



(a) Steady State

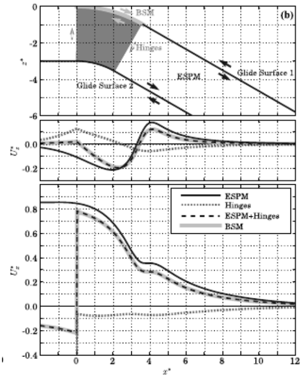


(b) Interseismic

Displacement field

Plate Model

Predicted displacements at the surface



Models

Vertical displacement

Horizontal displacement

In the limit when $H \to 0$: PM $\to$ BSM.

Plate Model

For interseismic period: we consider a **plate model**

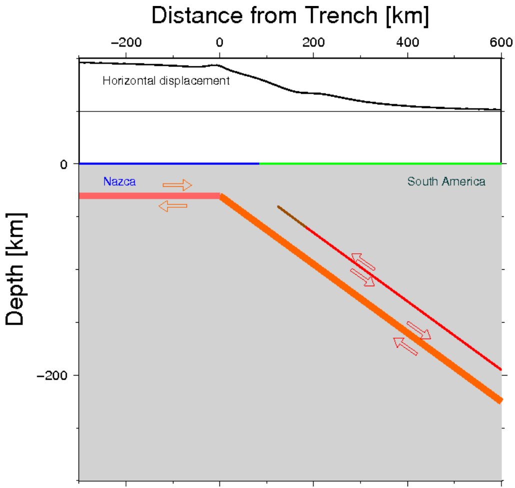


Plate Model

as a superposition of motion of

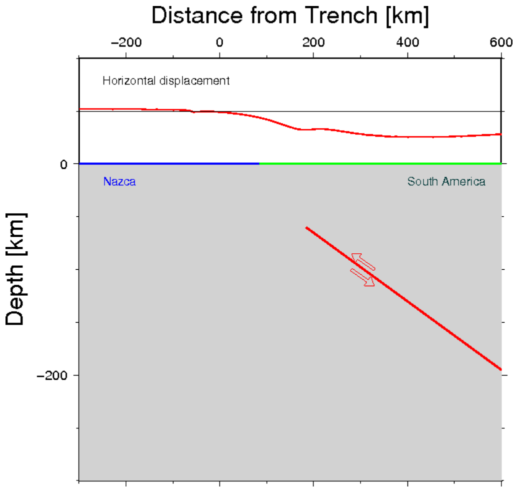
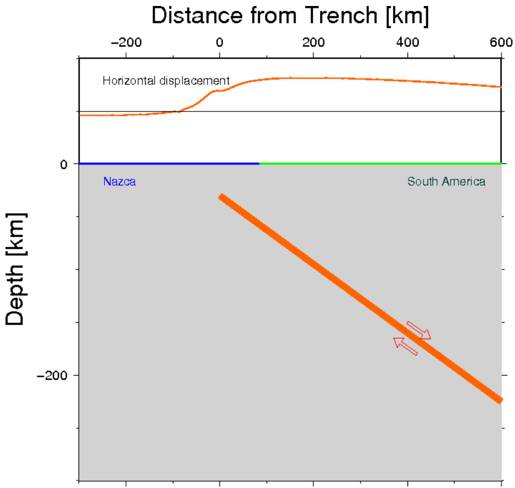


Plate Model

plus



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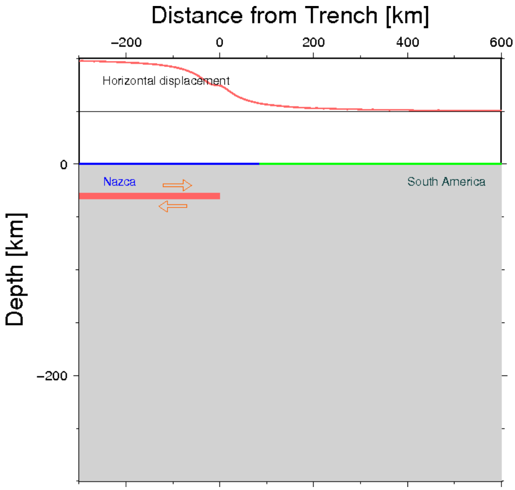


Plate Model

or a **back-slip model**

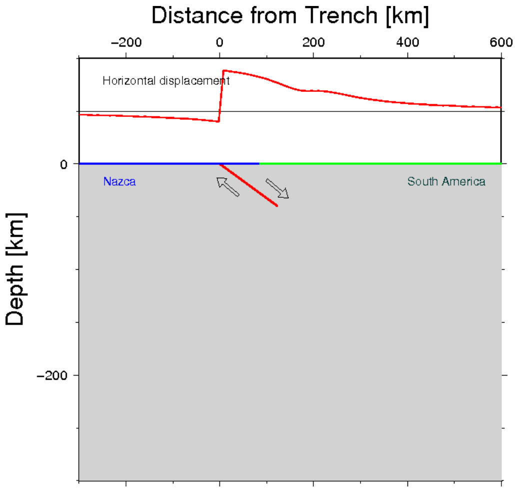
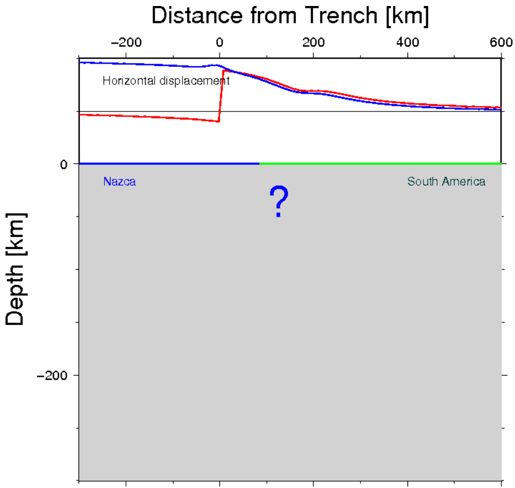


Plate Model

Comparison between back-slip model and plate model



Conceptual differences

Interseismic regime represents the earthquake **Loading Process**.

- In the Back-Slip Model one describes the motion **only** on the locking zone. This can not represent the loading process, therefore it is not reasonable.
- In the Plate Model one describes the motion on the whole plate. This is reasonable. It implies that with succesfull inversions, we can learn a lot of the movement of the whole plate. The role of the motion of the lower interface of the slab is important. So far, the interest has been only on the upper interface.

Outline

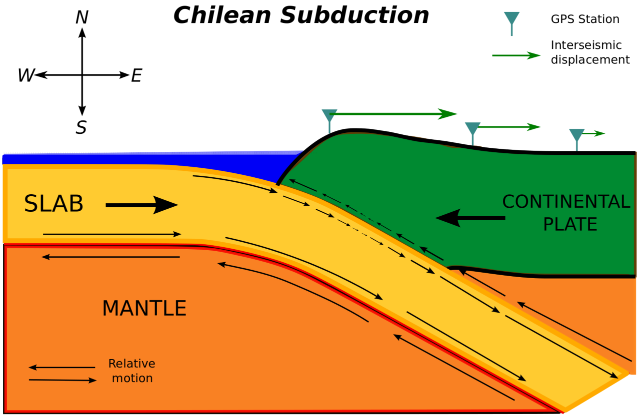
Geodetic Seismic Coupling

- Geodetic seismic coupling is defined as $gsc = (v_{plate} - v_{slide})/v_{plate}$.
- In BSM, v_{slide} is not consistently defined, because it is a reverse velocity, or is an ïmage solution", it is not real.
- In PM, v_{slide} is well defined, represents the slip in the coupling zone.

Outline

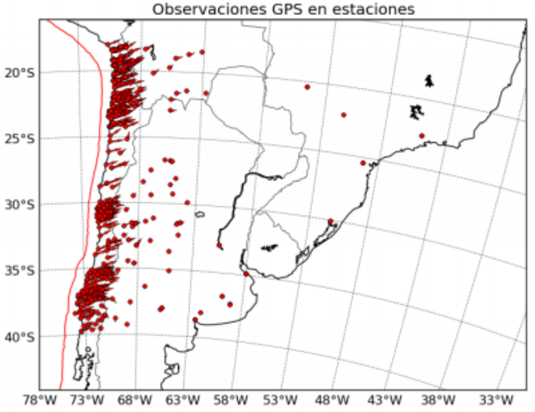
Seismic Coupling in Chile

Inverse problem to define each of the parameters: slip on each part of upper and lower interfaces, plate thickness, geometry of plate movement.



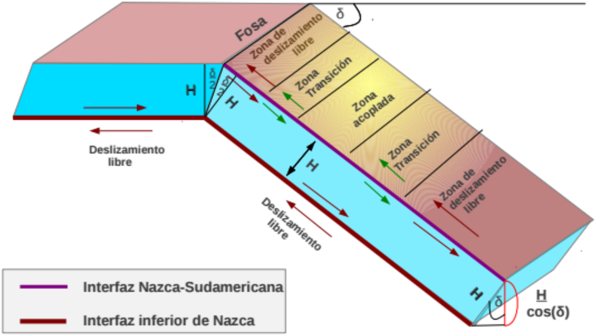
Inversion scheme

Observations



Inversion scheme

Simple parametrization



Coupling result for Maule Area

Sensitivity on slab thickness: from 5-100 km.

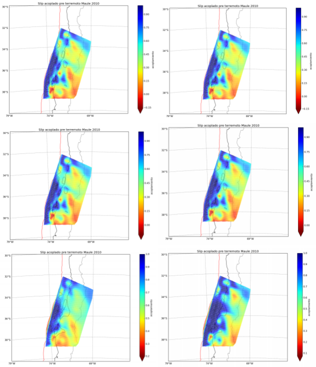
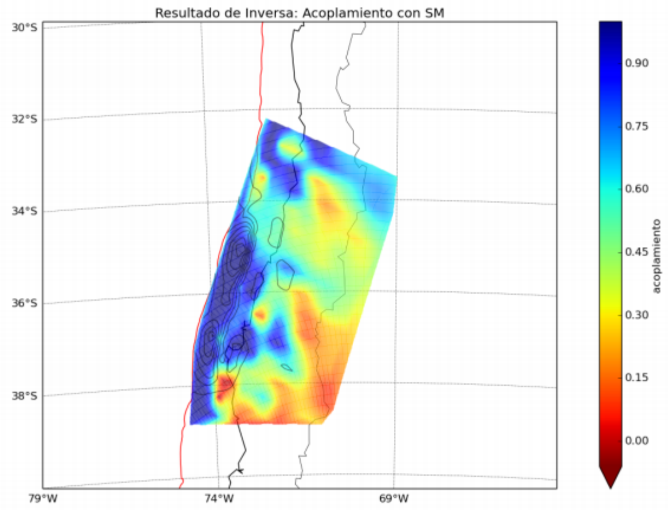
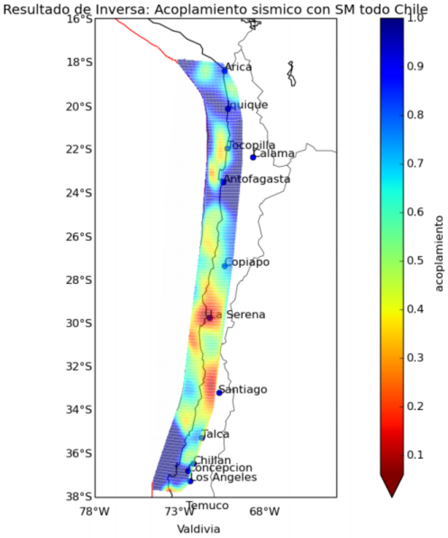


Figura 4.7: Distribución de la tasa de deslizamiento para distintos espesores de la placa de Nazca. Los espesores utilizados son: 5,10,20,30,50 y 100 kilómetros, ordenados de izquierda a derecha.

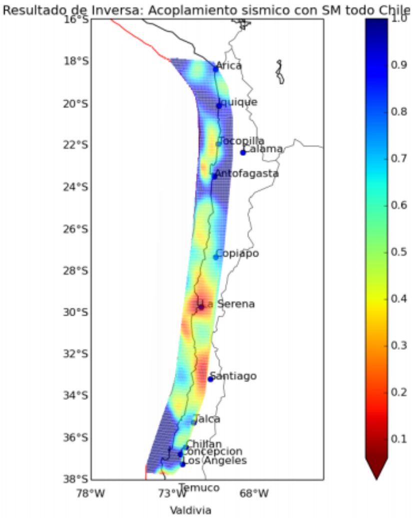
Maule area: Coupling compared with Coseismic

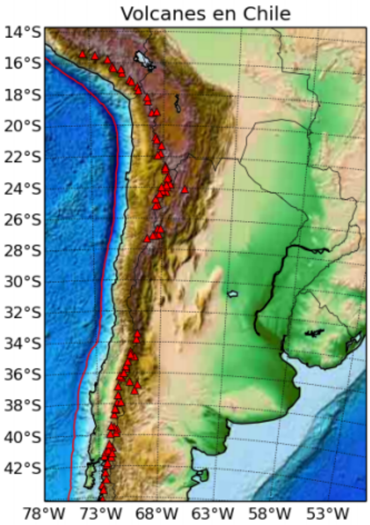


Coupling for Chile



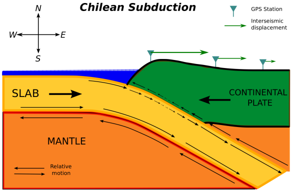
Coupling related to volcanoes ?





Outline

Conclusions



1. To exploit Quality data, we need good models. Back-Slip Model, which is widely used, is a first approximation, but it can easily be improved.
2. With Plate Model, we can retrieve important information from the motion of the complete slab.
3. Use of Plate Model allows determination of several parameters: plate thickness, depth of upper and lower transition zones, amount of creep, thickness of lower plate boundary zone.
4. Muchas gracias !