The 2007 Pisco earthquake (Mw8.0), a key event to understand the seismo-tectonic evolution of subduction zones

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ABSTRACT

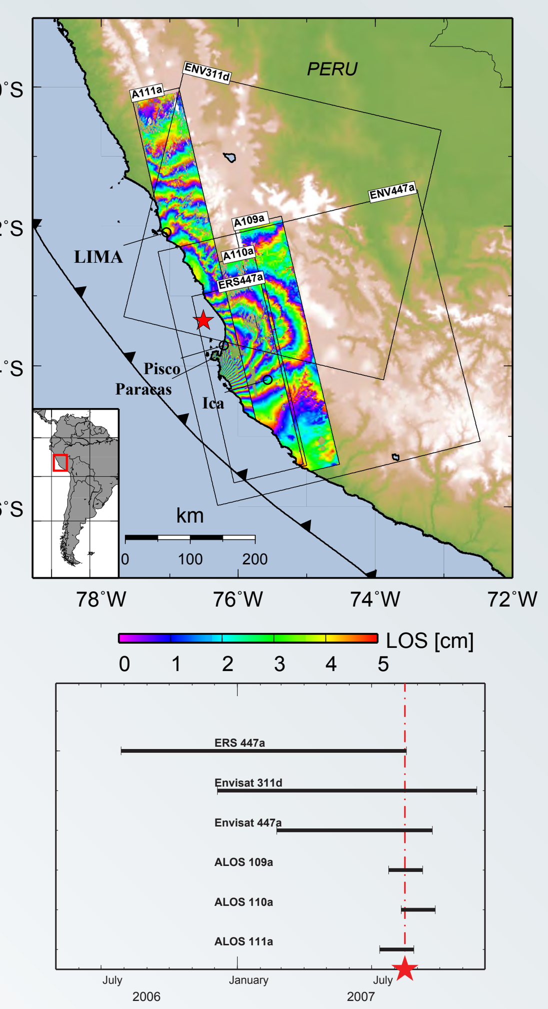
On August 15, 2007, an earthquake of Mw=8.0 struck the region of Pisco in Central Peru, and caused more than 500 victims. The event generated a local tsunami which resulted in increased destruction along the coast and at least 3 additional victims.

We use 6 InSAR images and teleseismic data to study the rupture process of this event. The configuration of the rupture as well as the quality of the data used for the inversion allow to obtain a robust and simple solution, whose validity is confirmed *a posteriori* by a large aftershock catalogue and tsunami data. The analysis of this event led to several important results:

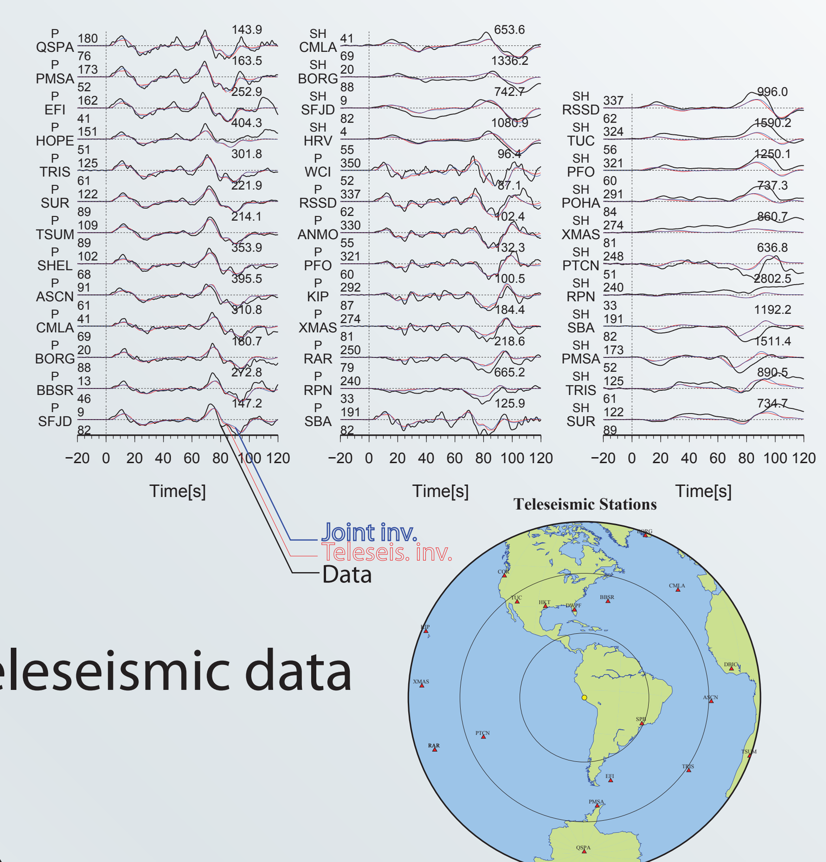
_the slip distribution is made of two distinct patches of high slip,
_the average rupture velocity is anomalously low (1 km/s). The setting of the rupture suggests that the rupture could have slowed down while propagating between the two asperities, but the data used here do not allow to distinguish between isolated asperities (triggered slip), and complex rupture propagation,
_the 2007 rupture filled a previously identified seismic gap, and left a 80 km segment centered on the Nazca ridge unbroken. Historical accounts suggest that this later segment might have not experienced any large earthquake during the last 500 years,
_the down-dip limit of the rupture follows the complex shape of the coastline, confirming a long suggested link,
_areas of high aftershock density accurately outline the areas of high coseismic slip, suggesting that this type of observation could be used to better constrain source models. Campaign GPS indicate that zones of high aftershock density correspond to areas of strong after-slip. Most of the after-slip is centered on the Nazca ridge,
_the inversion performed using deep-ocean tsunami data give very promising results, but complementary tests need to be performed in order to fully understand the limitation of this type of data

SOURCE ANALYSIS

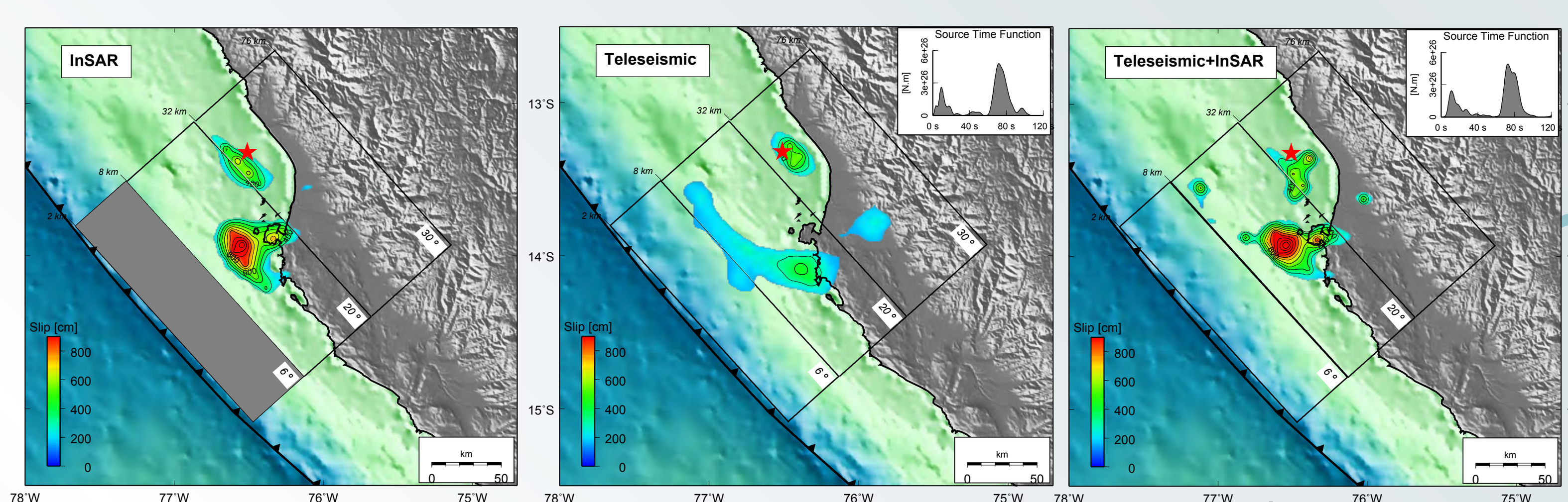
For an accurate and robust image of the rupture



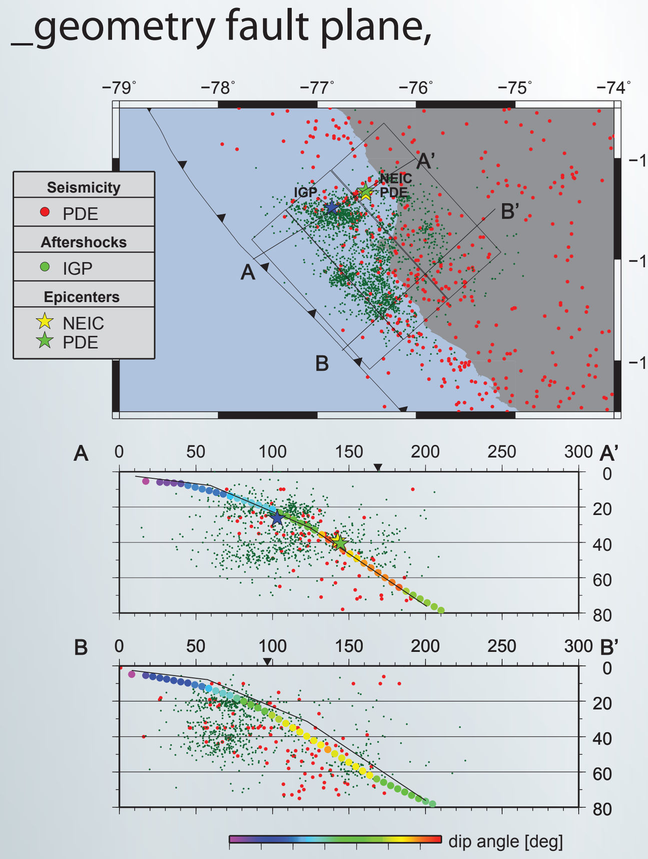
InSAR data & Teleseismic data



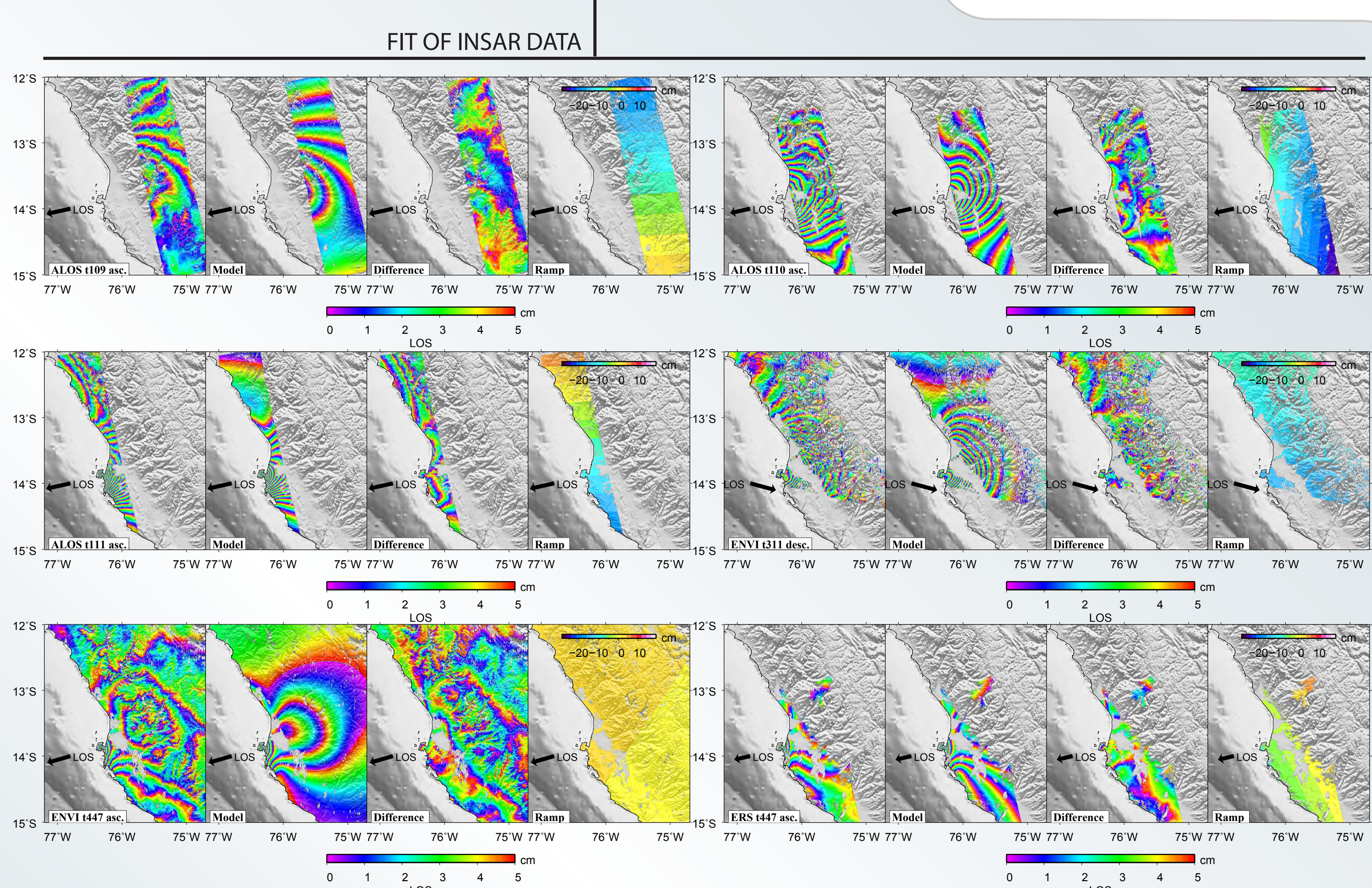
Inverted slip models



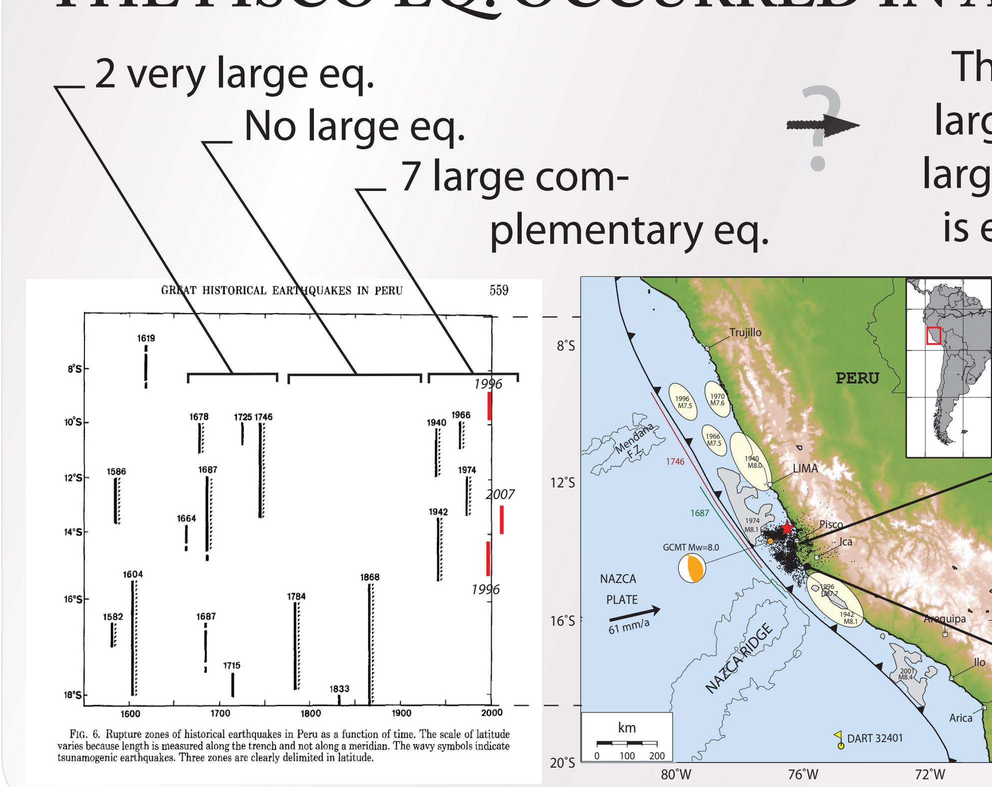
Assumptions:
_1D earth model,
_linear ramp correction,
_little post-seismic,
_geometry fault plane,



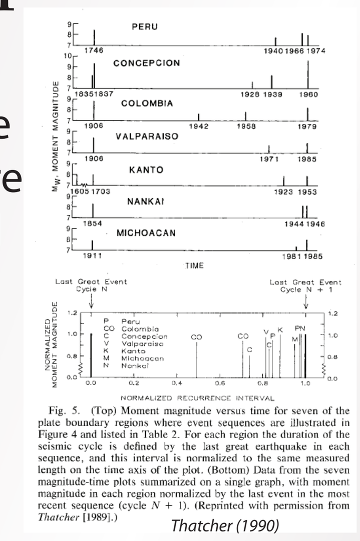
FIT OF INSAR DATA



THE PISCO EQ. OCCURRED IN A SEISMIC GAP



Thatcher model (1990): large eq. tend to precede largest ones. At least there is evidence of a bimodal mode of rupture

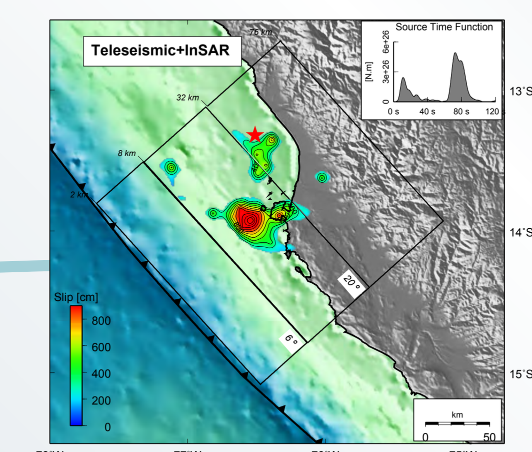


The Pisco earthquake occurred in what was previously identified as a seismic gap.

INTERPRETATION

What can we learn from this model?

Coseismic slip is usually distributed parallel to a linear coastline. The sharp S bend of the Pisco coastline allows to shed light on the relation between earthquake and topography.

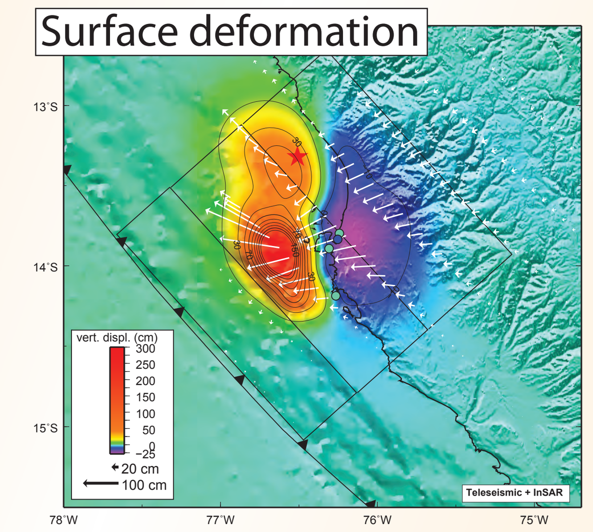


The Pisco earthquake is probably the first event for which we are able to get a reliable source model as well as a very complete aftershock catalog and GPS measurements of the post-seismic slip. This unique combination of data allows to better understand the transition from coseismic to inter-seismic.

The InSAR and teleseismic data indicate that the average rupture between the 2 asperities was very slow (1 km/s). However, we cannot distinguish whether the rupture was very slow and constant, or if it propagated at a standard speed and stopped on its way to the second asperity.

The tsunami generated by the 2007 Pisco earthquake was one of the first large events to be recorded by deep-ocean pressure sensors. Those records are not affected by non-linear coastal amplification.

DOWN-DIP LIMIT OF EQ. IS RELATED TO COASTLINE POSITION



Confirms the observation that the down-dip limit of rupture matches the coastline.
→ The sharp bend of the coastline indicates that this is not a coincidence.

Uplift pattern anti-correlated with topography
→ Topography correlates deformation of the inter-seismic period.

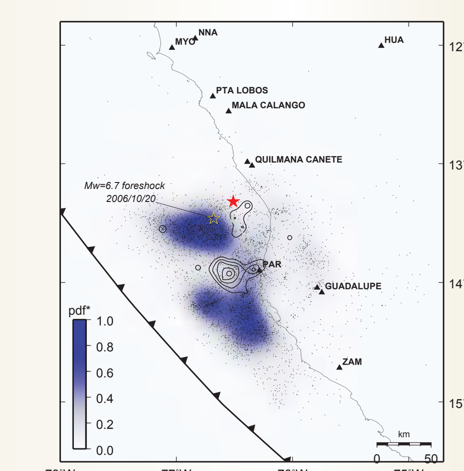
Tendency of asperities to correlate with gravity low and basins Wells et al. (2003), Song & Simons (2003)

TOPOGRAPHY ↑ ? controls ↓ SEISMIC CYCLES

Long term vertical deformation rate (1.5mm/300y.) is very small compared to the deformation of one seismic cycle (2m/300y.)

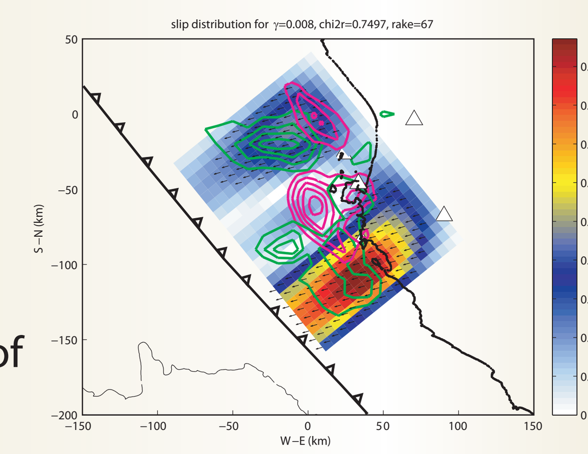
AFTERSHOCKS OUTLINE ASPERITIES

The right figure shows 45 days of aftershock activity recorded by a local network of 12 stations (triangles). The dark blue color correspond to areas with a high density of aftershocks (computed using a gaussian kernel estimator), and emphasize the anti-correlation with areas of large coseismic slip.



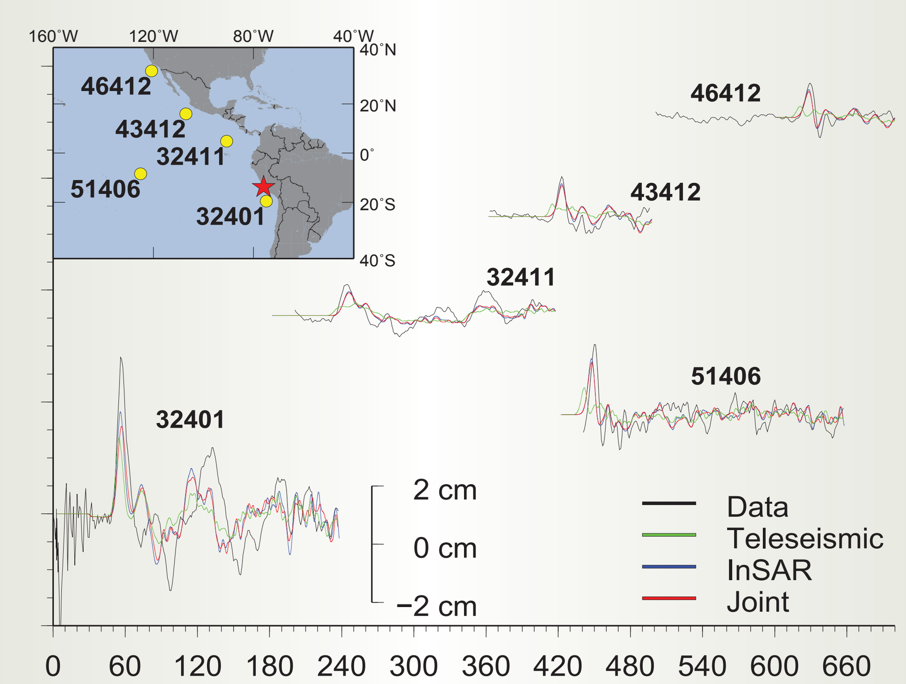
AFTERSLIP ALONG THE NAZCA RIDGE

Post-seismic slip inverted from a temporary but continuous network of GPS stations. The analysis is performed using the PCA method. The pink contours correspond to the areas of high coseismic slip, while the green contours show the areas of high aftershock density.



TSUNAMI DATA TO CONSTRAIN EQ. RUPTURE MODELS

Forward simulation of the teleseismic, InSAR and joint slip models



Inversion of the tsunami data

Coarse discretization gives a solution very close from the joint inversion.

Inversion becomes unstable with a higher number of subfaults. Even with smoothing and moment damping.