



OSUG@2020

Documenting the long-term preparation phase of a megathrust earthquake: *Case of the 2014 North Chile Mw8.1 event*

Anne Socquet

Jorge Jara, Jesus Piña Valdes,

Fabrice Cotton, David Marsan, Michel Bouchon

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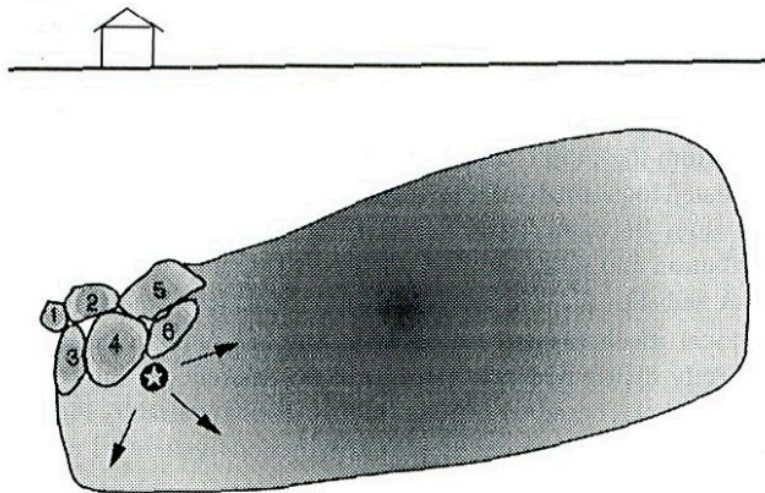
Francisco Ortega-Culaciati, Daniel Carrizo, Edmundo Norabuena



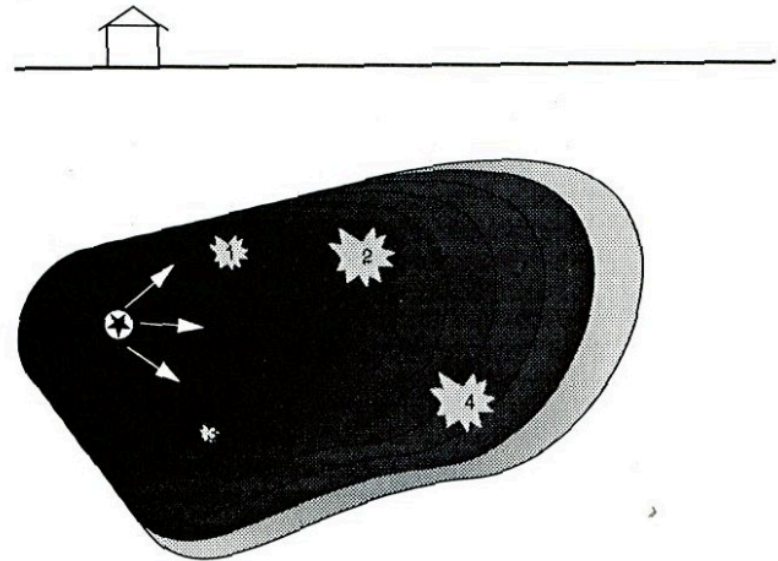
Nucleation of earthquakes

Two models :

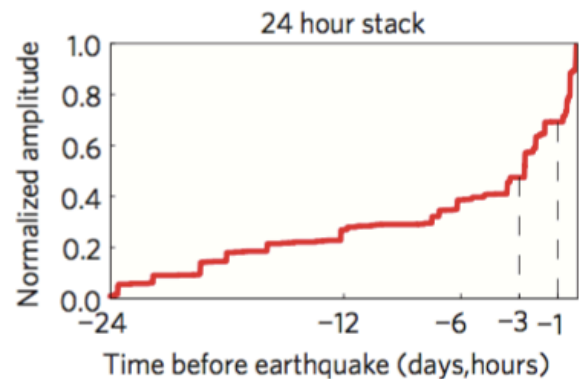
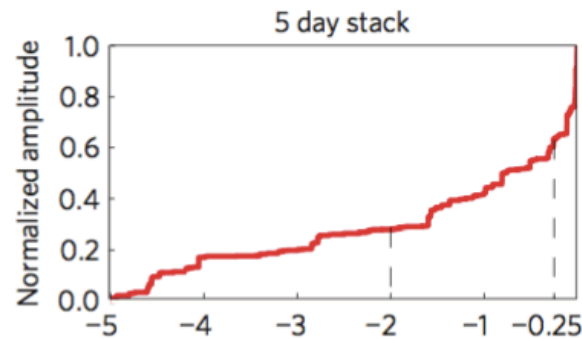
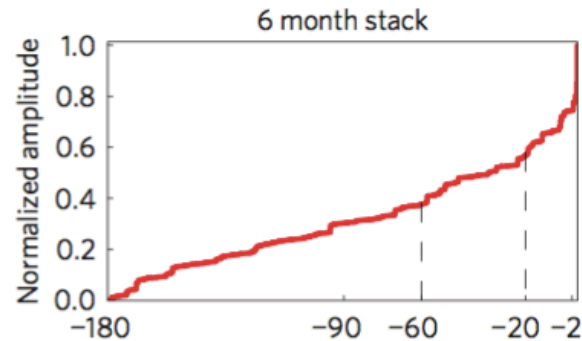
Slow cascade



Preslip triggering

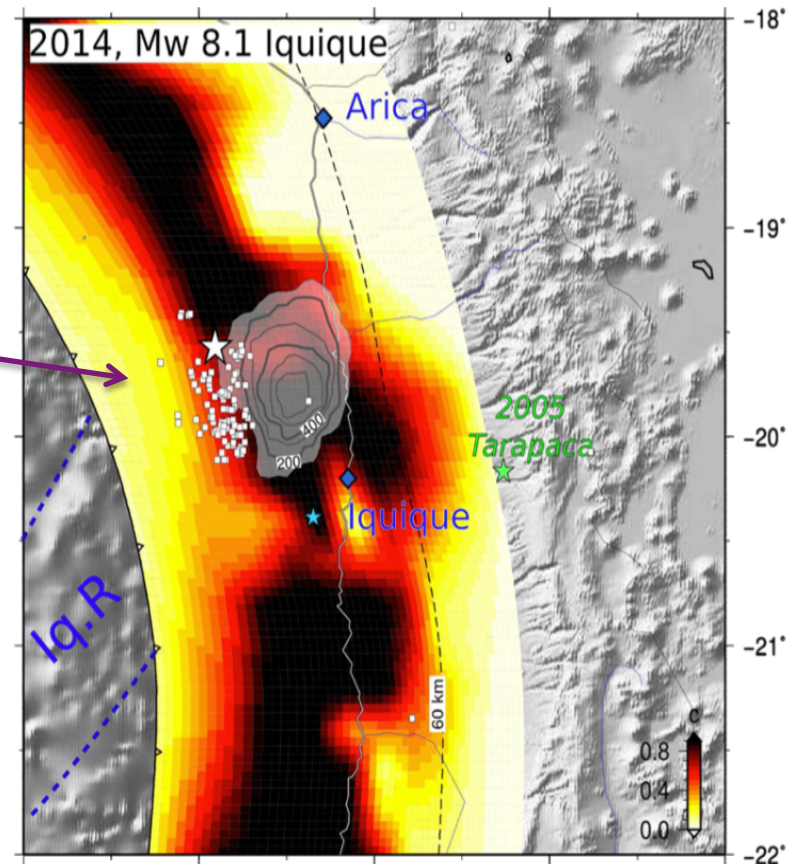
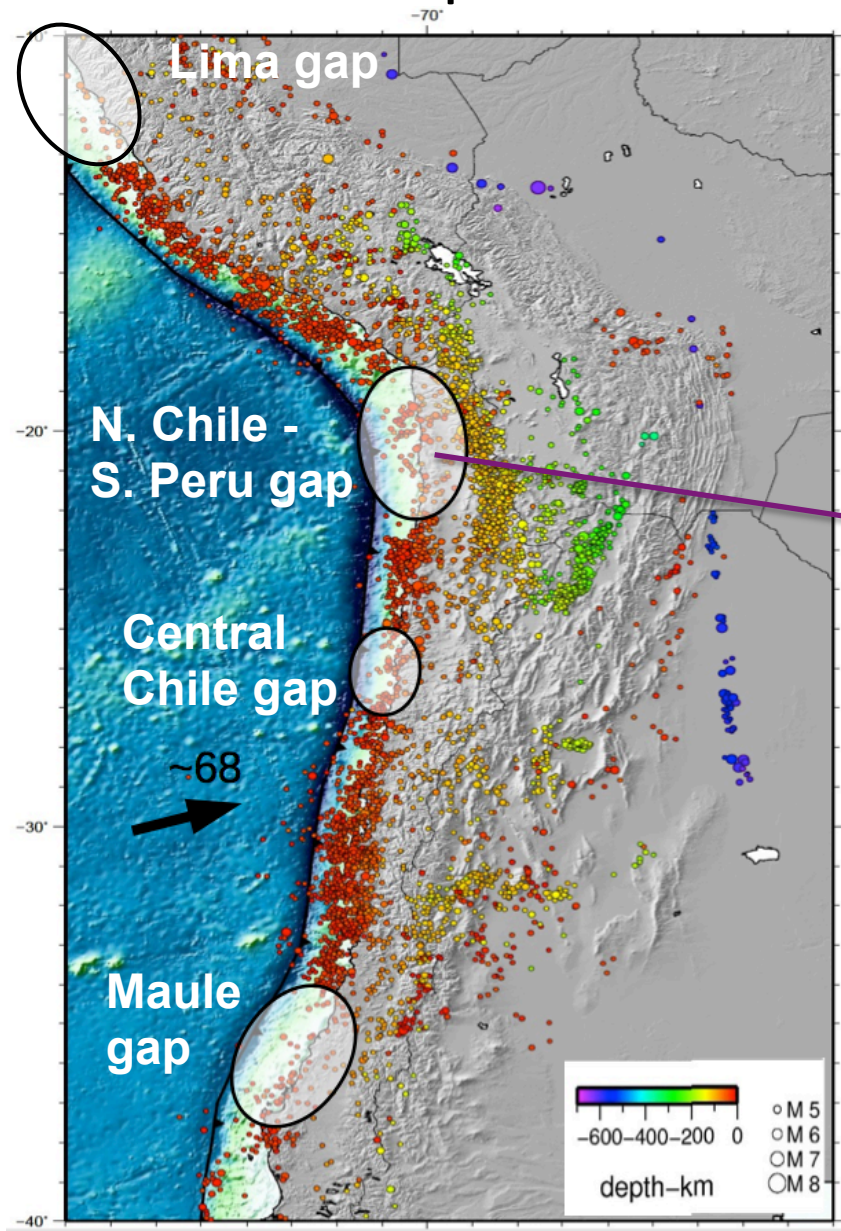


Most large interplate earthquakes have a long precursory phase...



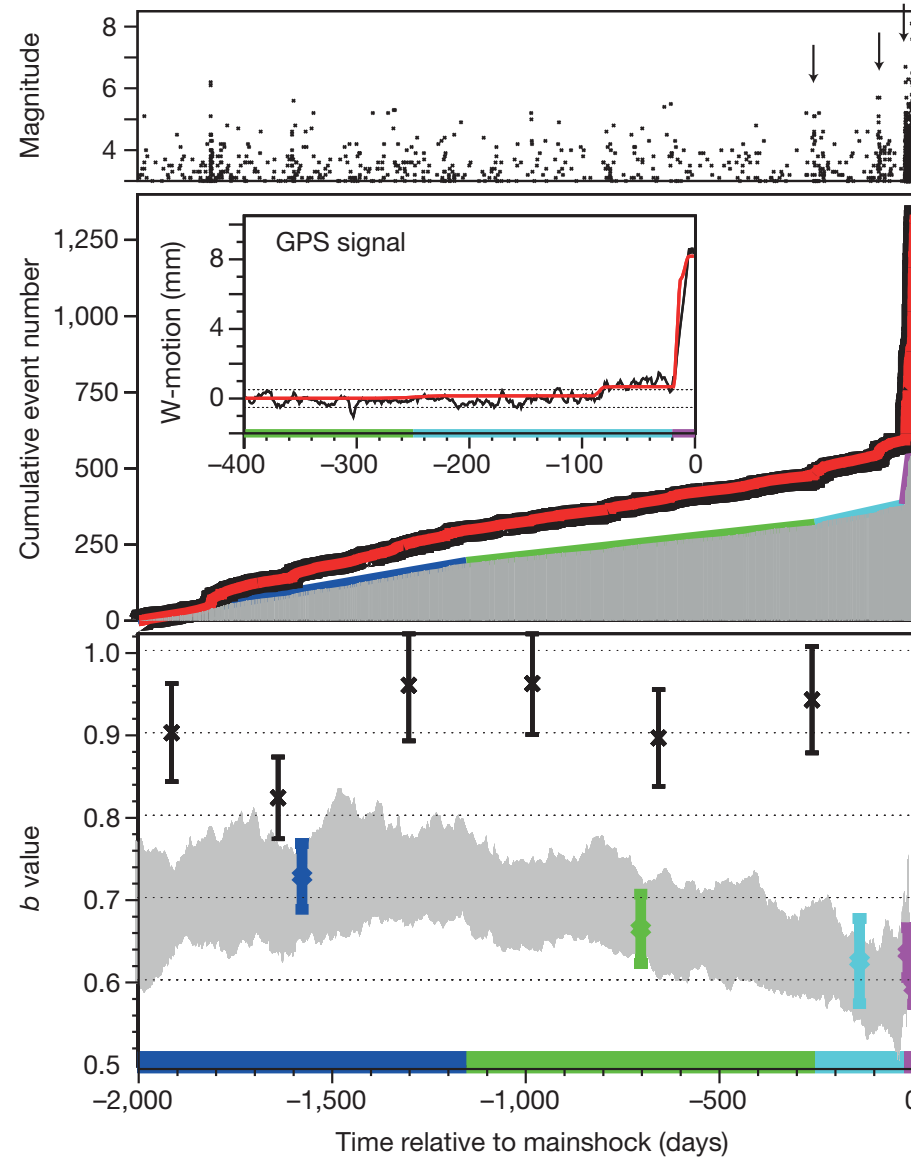
Normalized stacks of the cumulative seismic moments of 25 interplate sequences

Mw8.1 2014 Iquique earthquake (North Chile) was preceded an intense foreshock activity



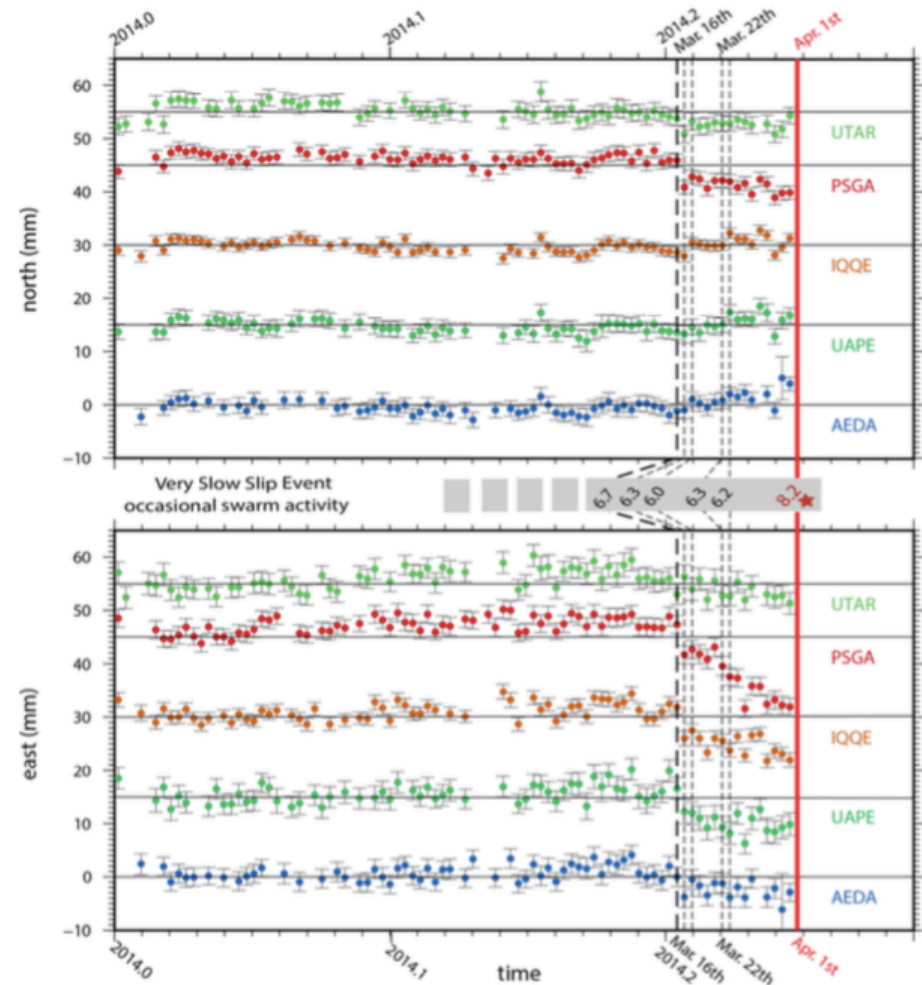
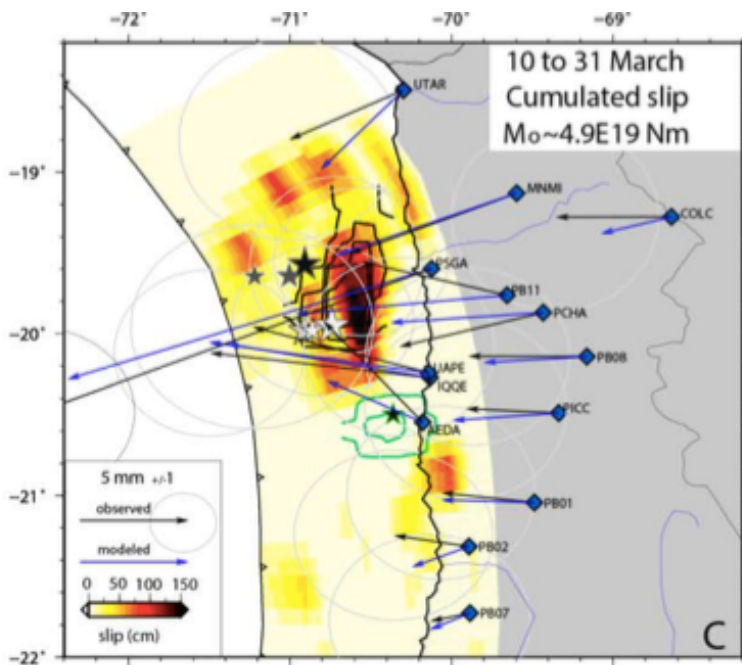
[Metois et al., 2016, *PAGEoph*]

Increased background seismicity 15 days before Iquique Earthquake



(Schurr et al. 2015)

... and strong 15-day deformation transient visible in cGPS time series



But interpretation (cascade or preslip) differs from one study to the other....

(Ruiz et al. 2015)

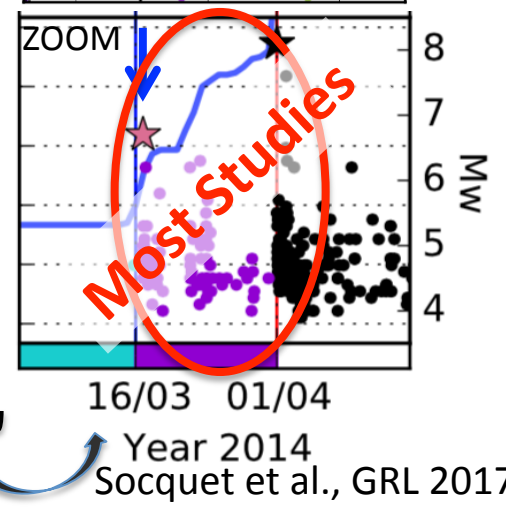
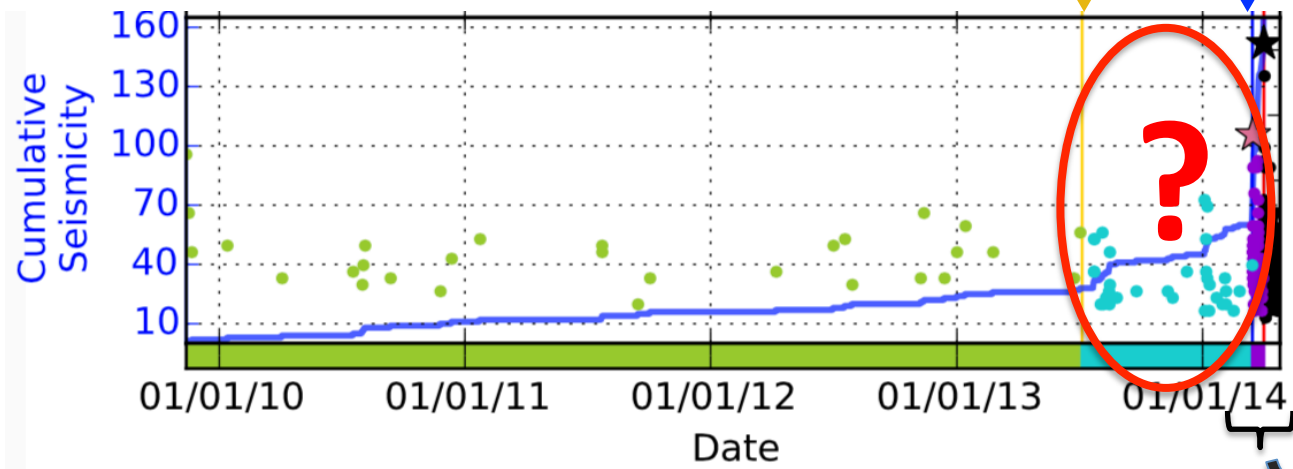
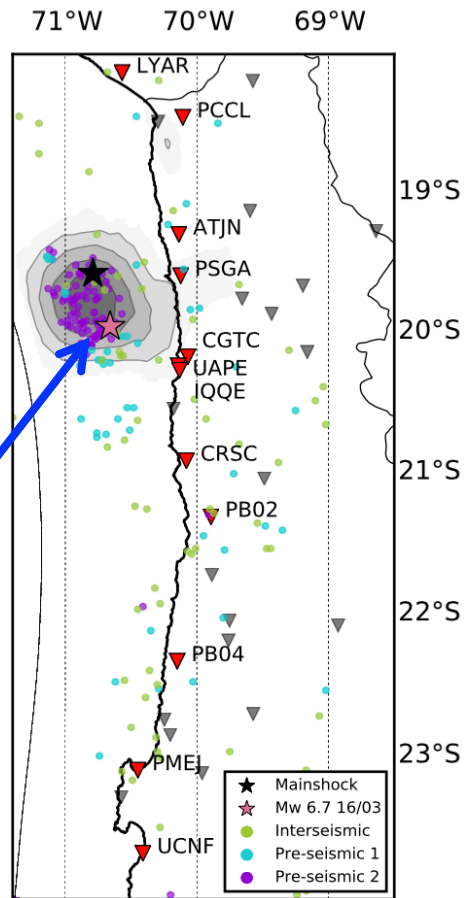
Mw8.1 2014 Iquique earthquake was preceded by intense foreshock activity

Most of the studies focused on the 15-days preceding the mainshock (after largest foreshock Mw6.7, March 16th, 2014)

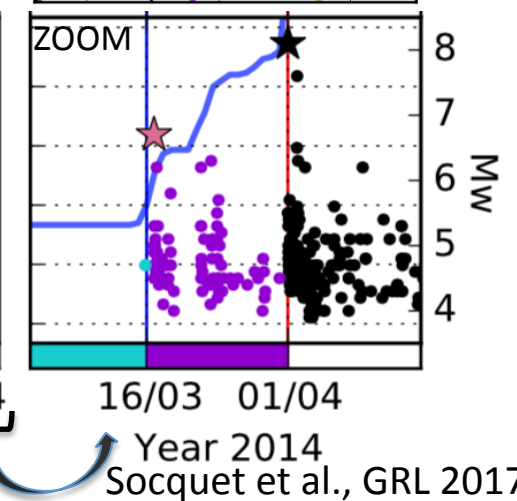
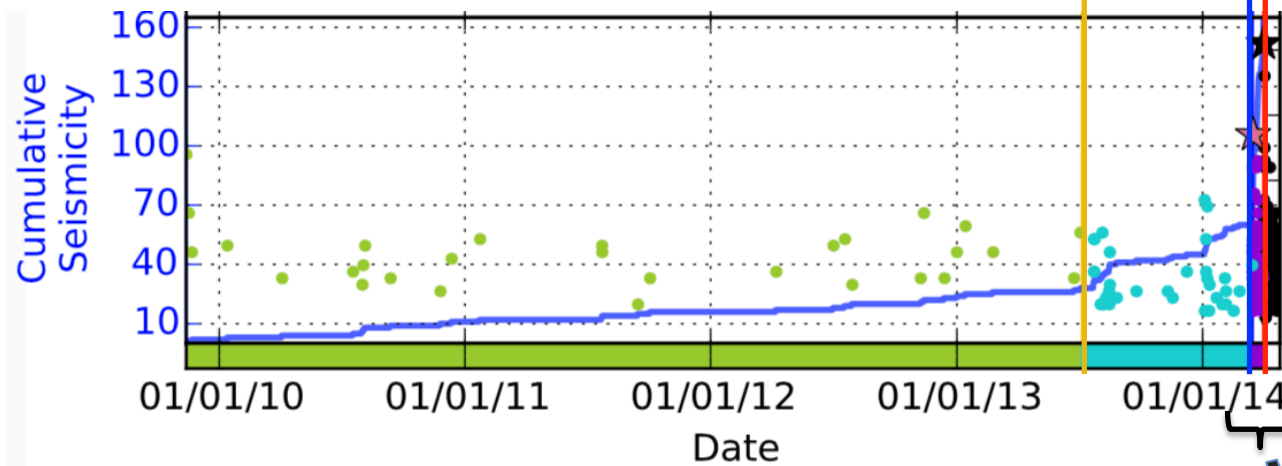
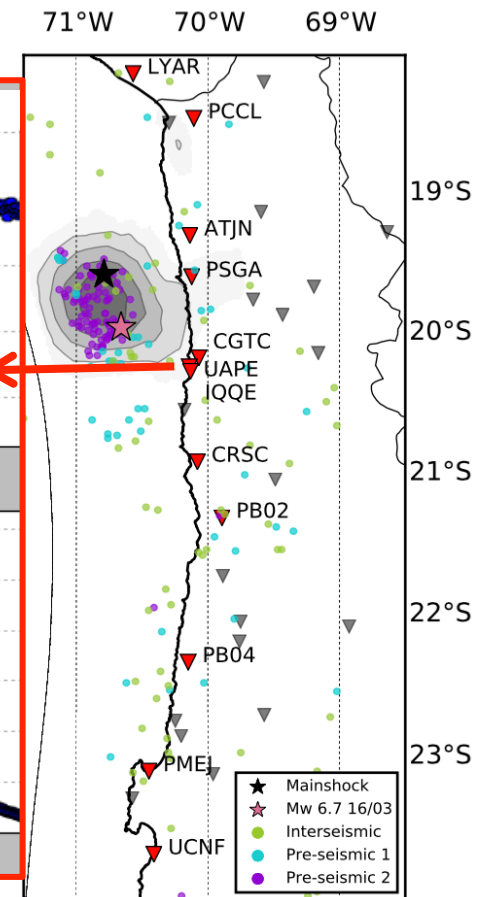
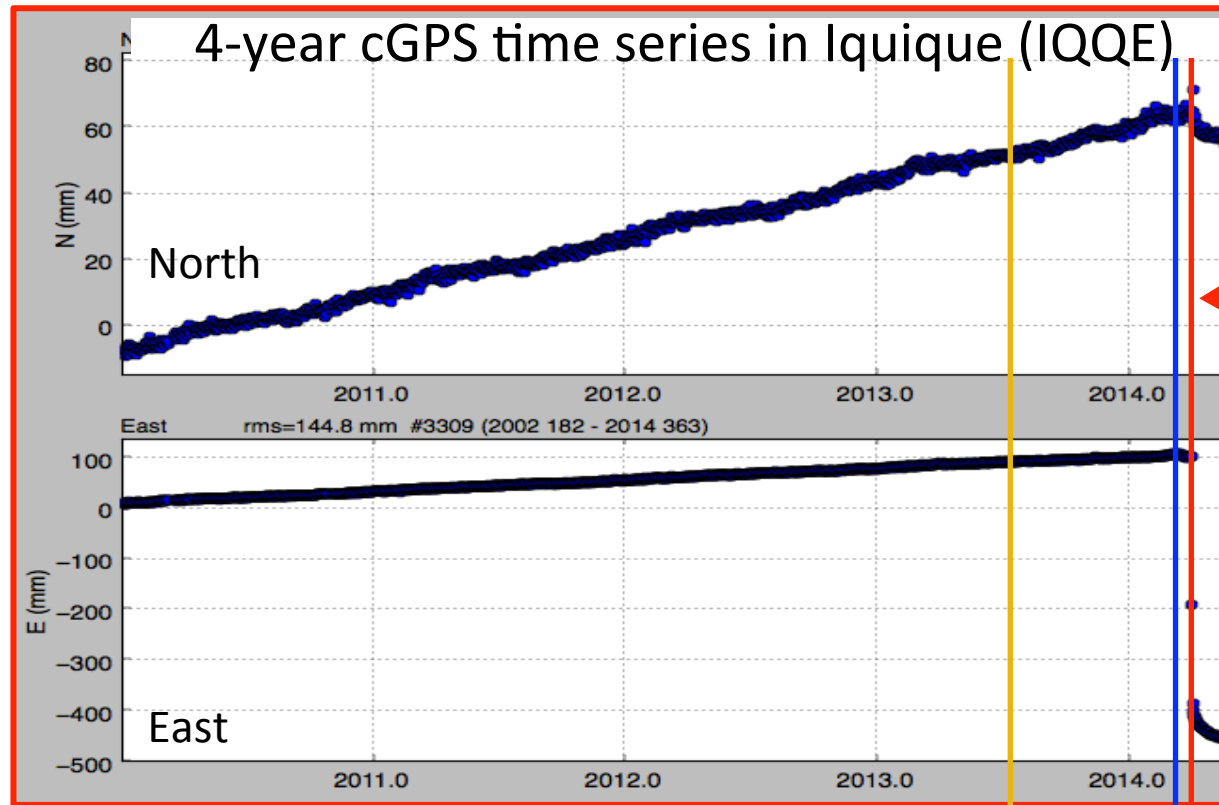
Very little is known about a potential long-term precursor...
→ Combination of geodesy & seismology at the **monthly, yearly, decadal** timescales

March 16th 2014
Largest foreshock Mw6.7

July 2013



At the timescale of **a few months, years...**

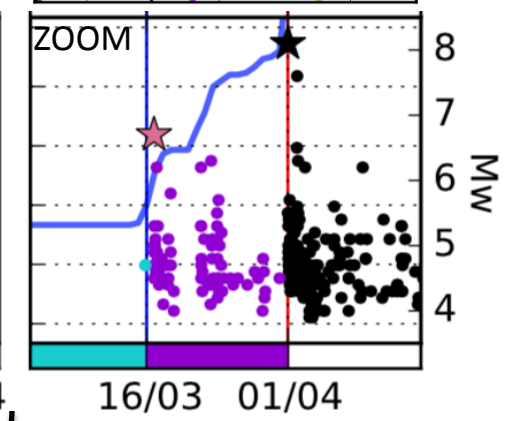
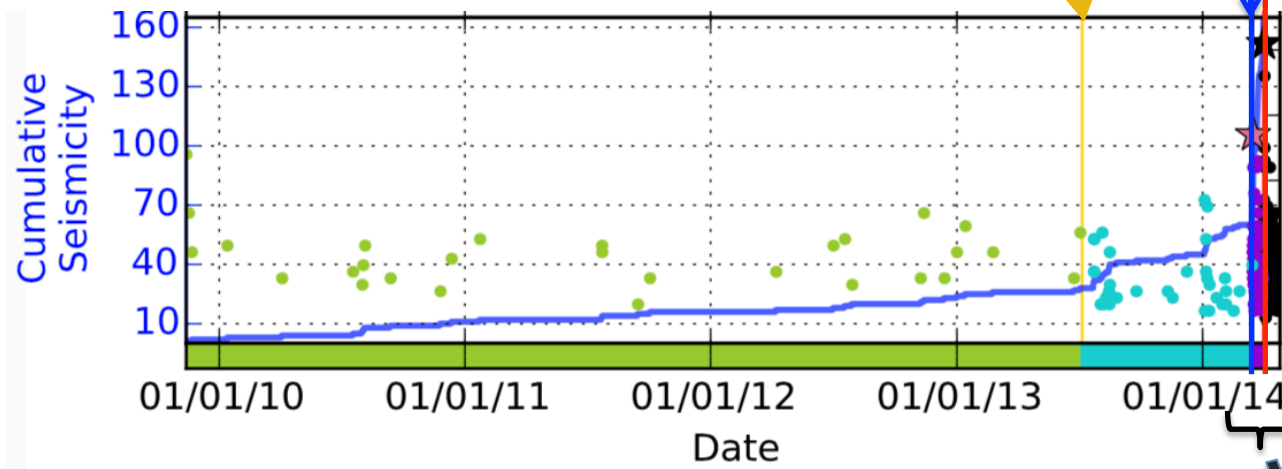
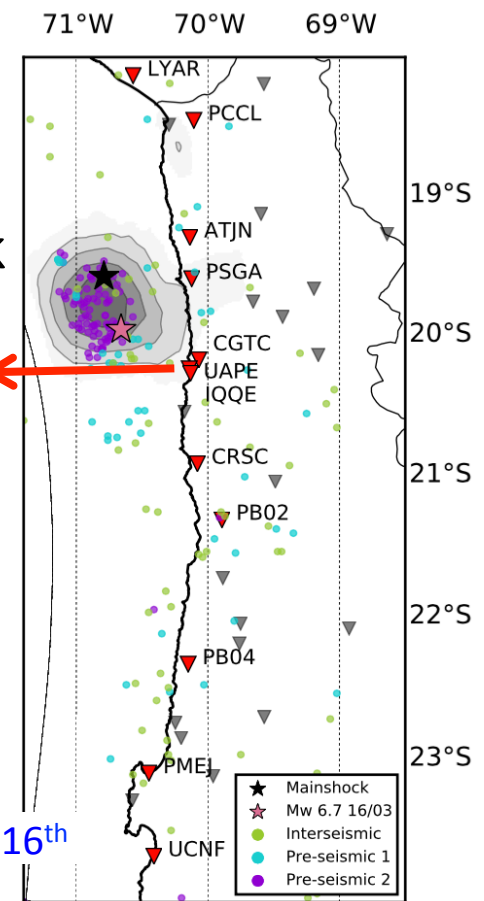
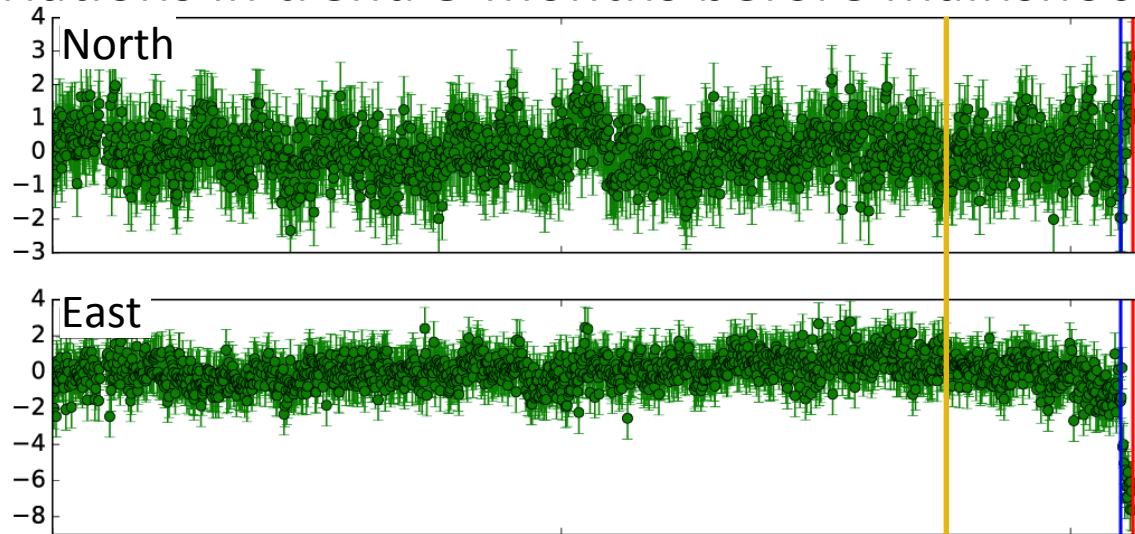


4-year cGPS time series in Iquique (IQQE)

→ detrended

→ Large signal after Mw 6.7 foreshock

→ Variations in trend 8-months before mainshock



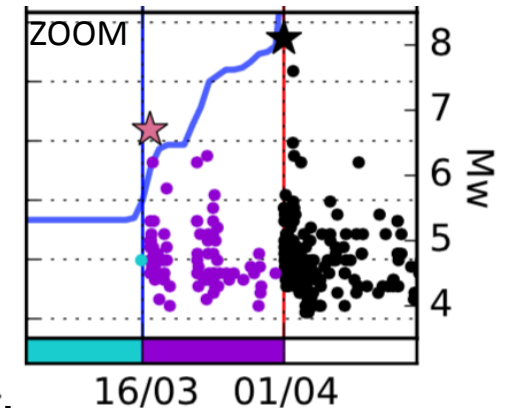
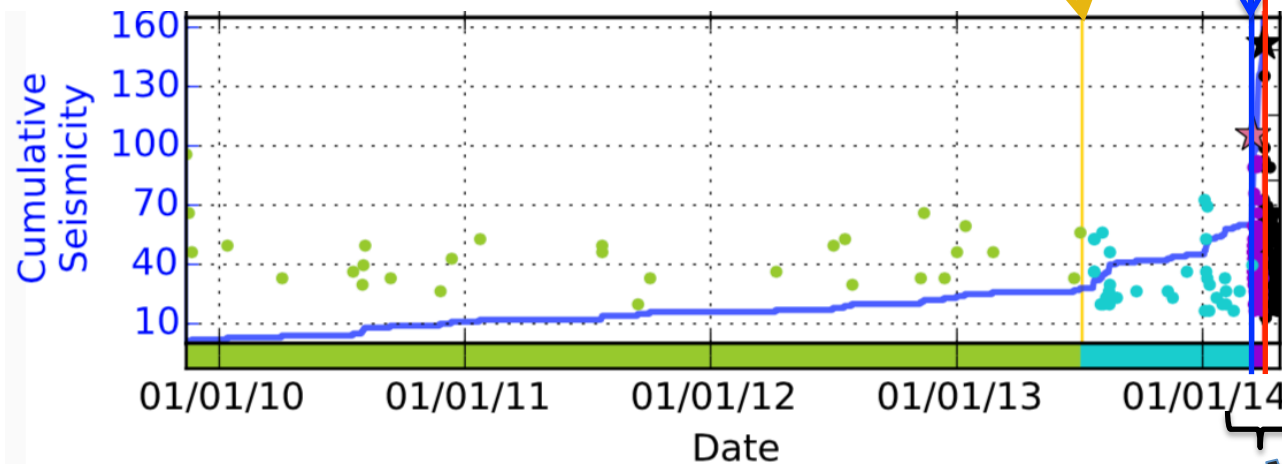
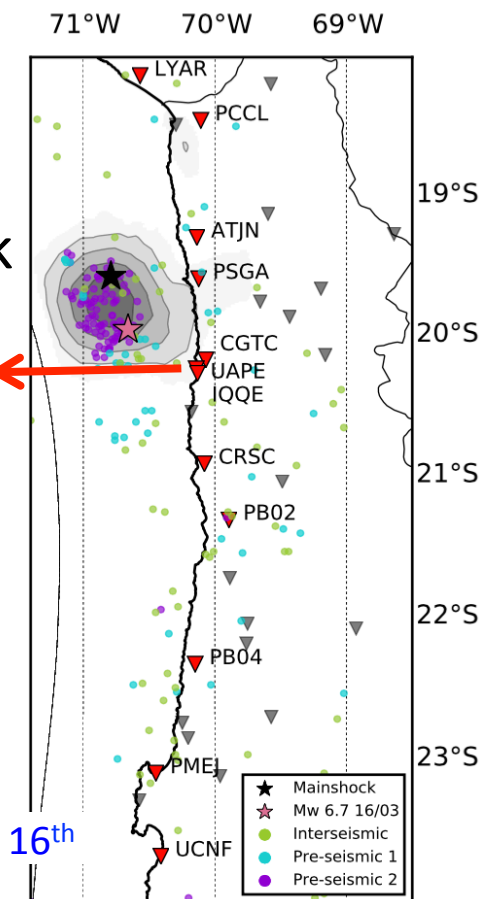
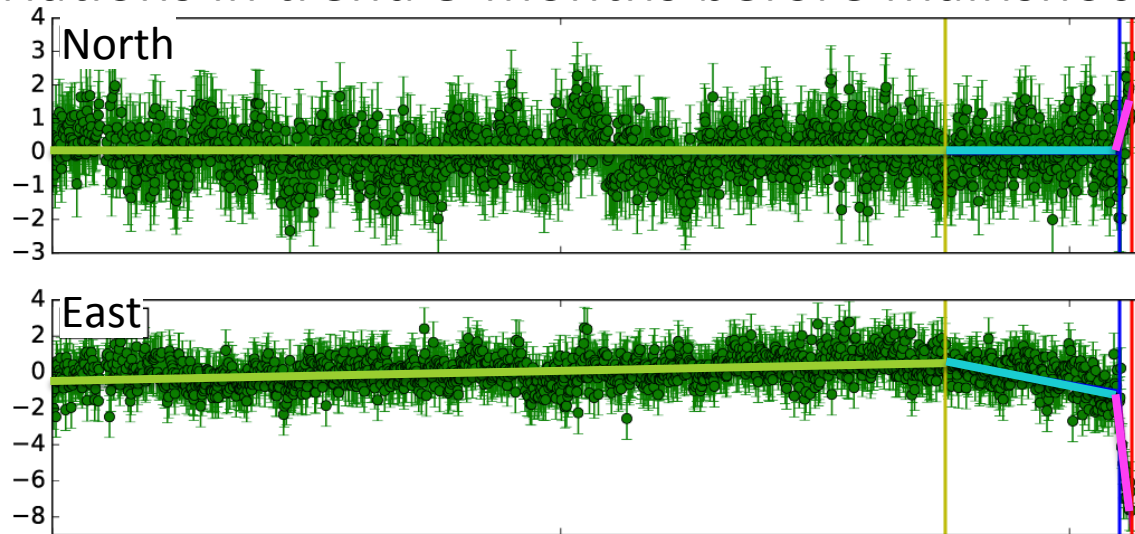
Year 2014
Socquet et al., GRL 2017

4-year cGPS time series in Iquique (IQQE)

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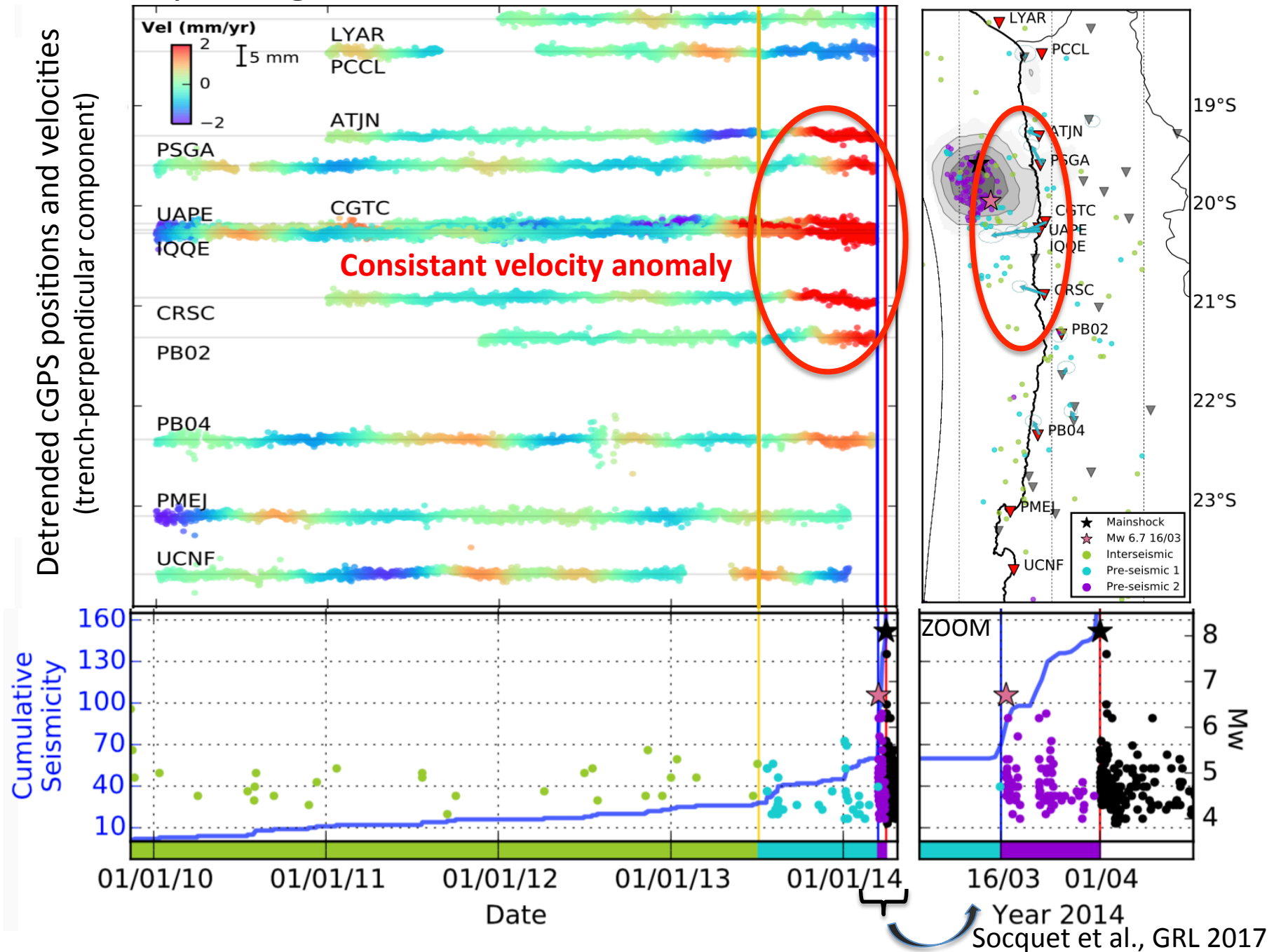
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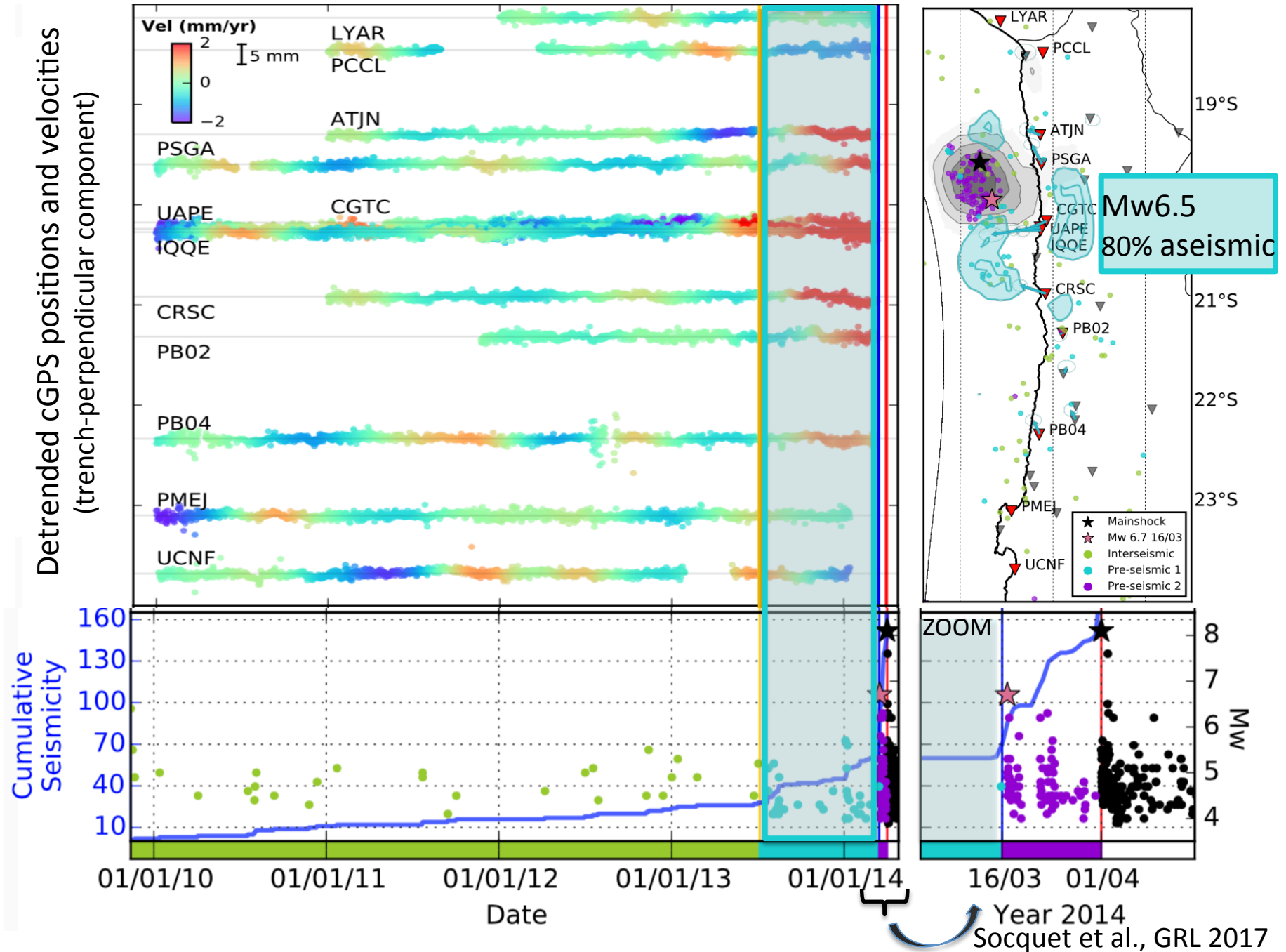


Year 2014
Socquet et al., GRL 2017

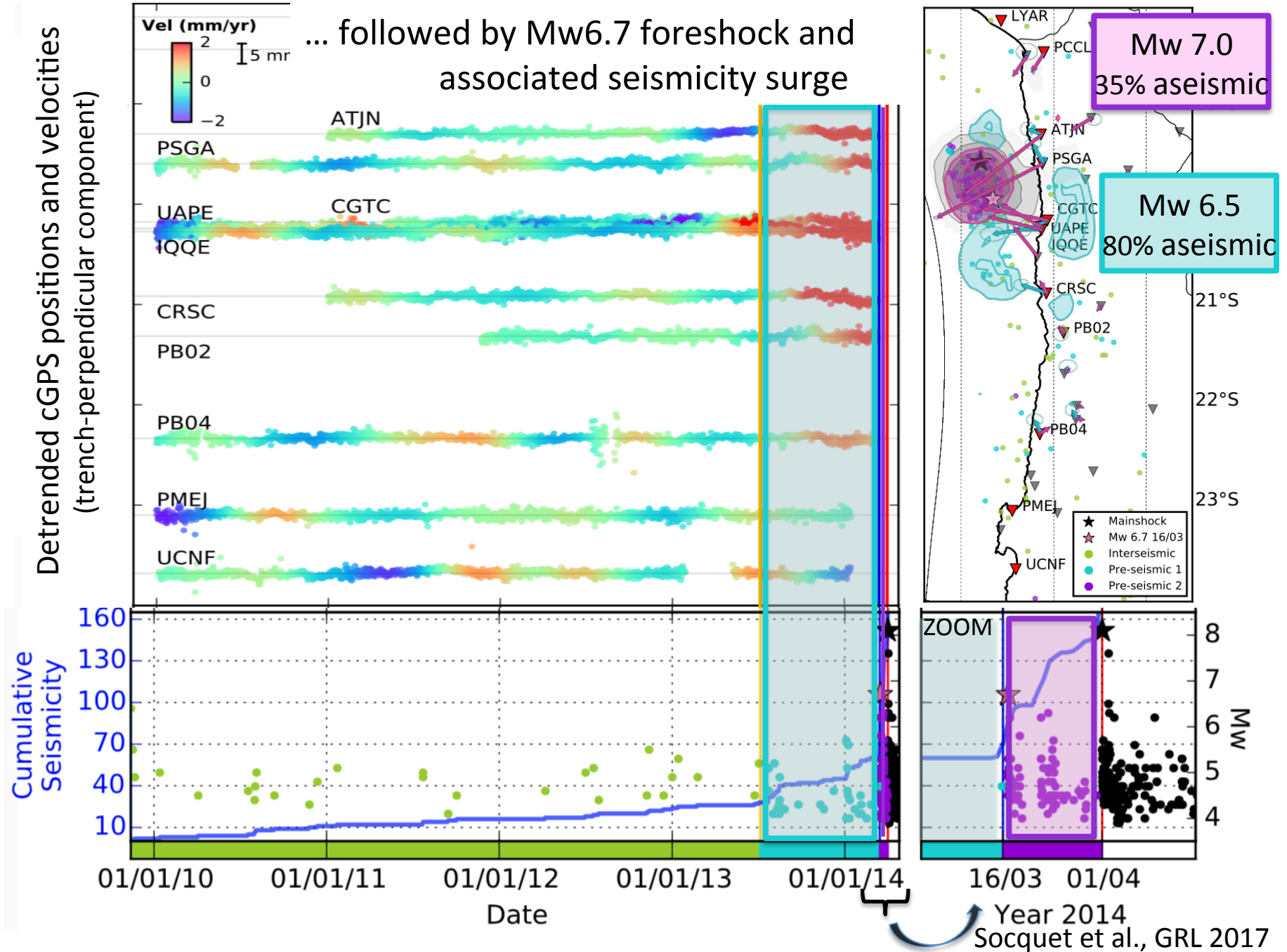
Velocity change in coastal cGPS time series



An 8-month preseismic slow slip event...

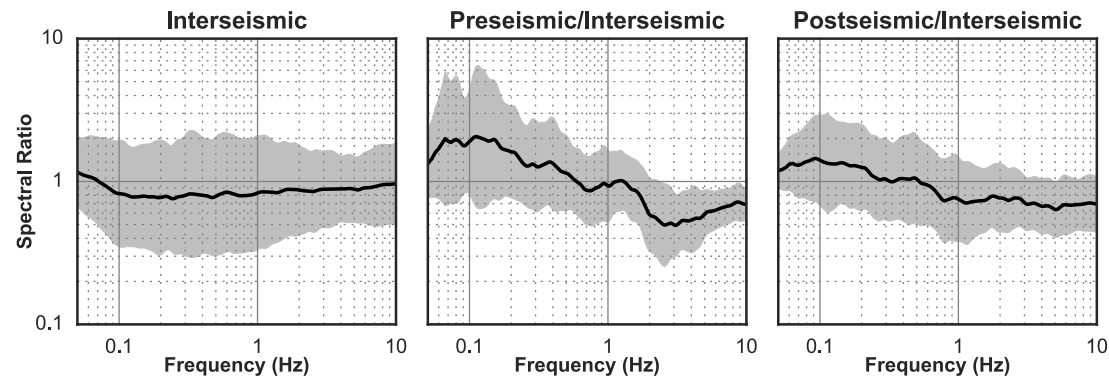


An 8-month preseismic slow slip event...

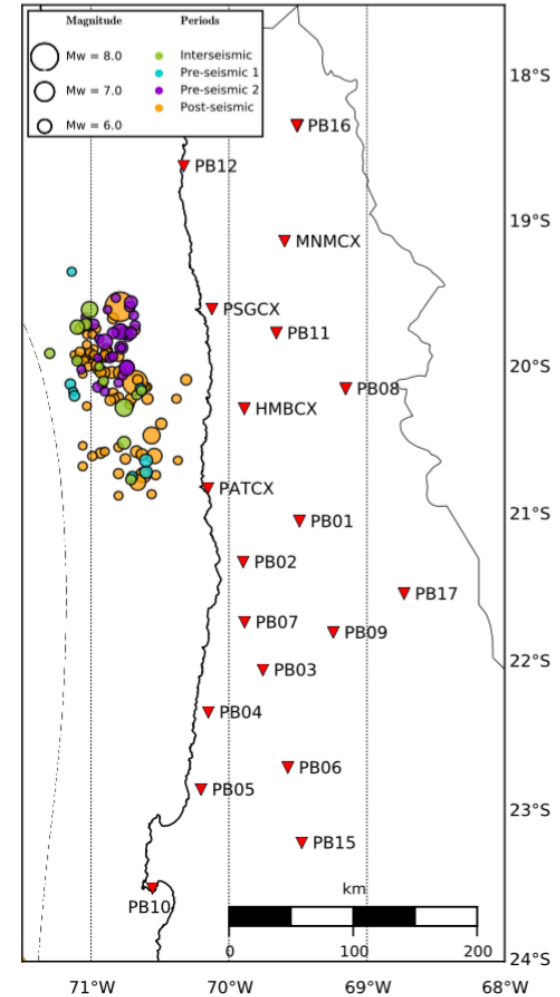


What signature in foreshock Frequency content?

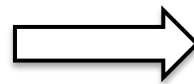
Spectral ratios of interface seismicity



Piña Valdes et al., BSSA 2018



- ! Depends on:
- Earthquake Magnitude
 - Distance to the station
 - Path effects
 - Site effects



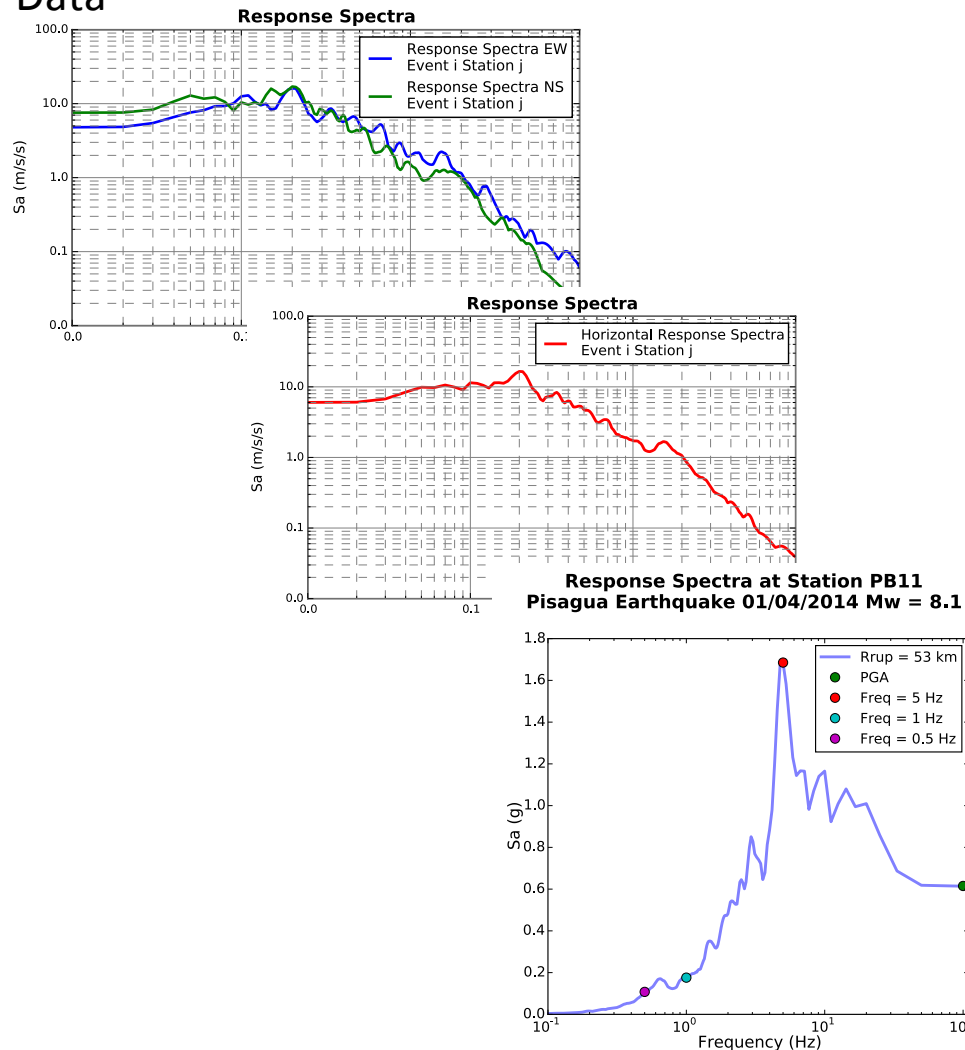
Couples of comparable events :

- $\Delta M_w \leq 0.1$
- distance < 25 km

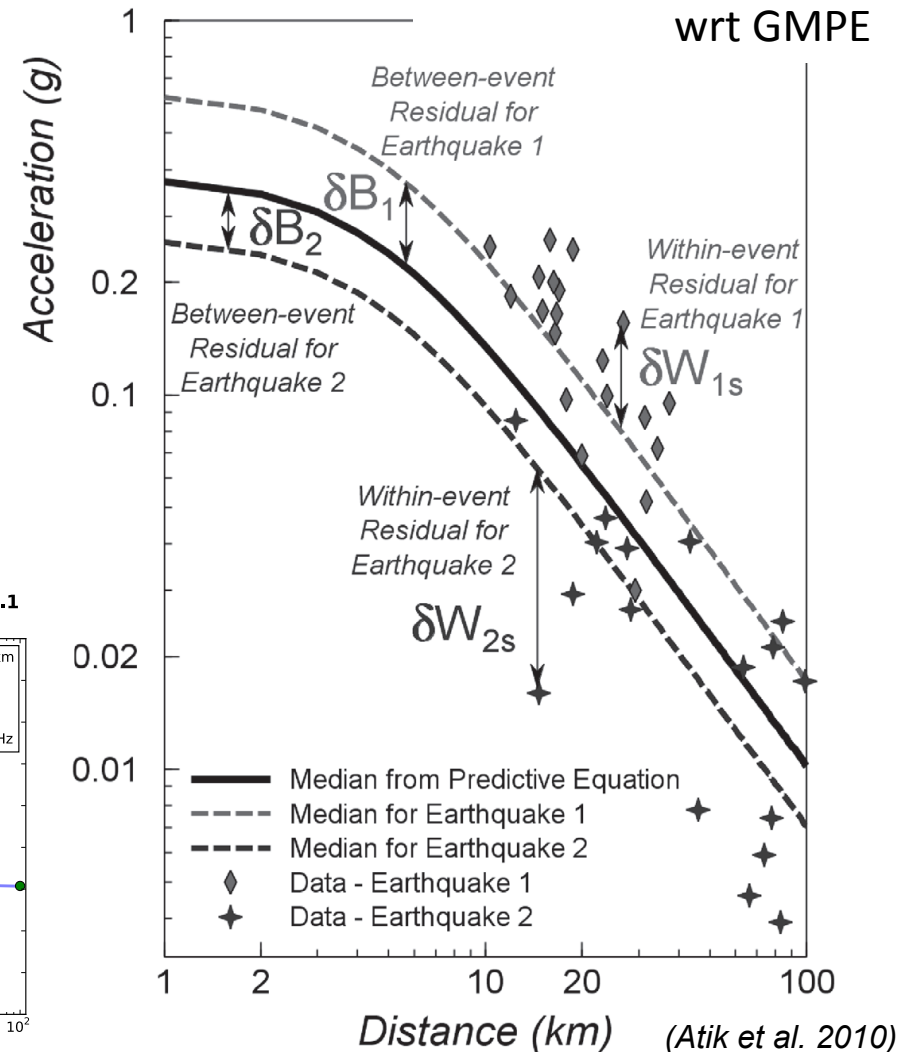
= only a subset of our data set

What signature in foreshock Frequency content? Using Ground Motion Prediction Equations (GMPE's) as a Backbone

Data



Scheme of residuals
wrt GMPE

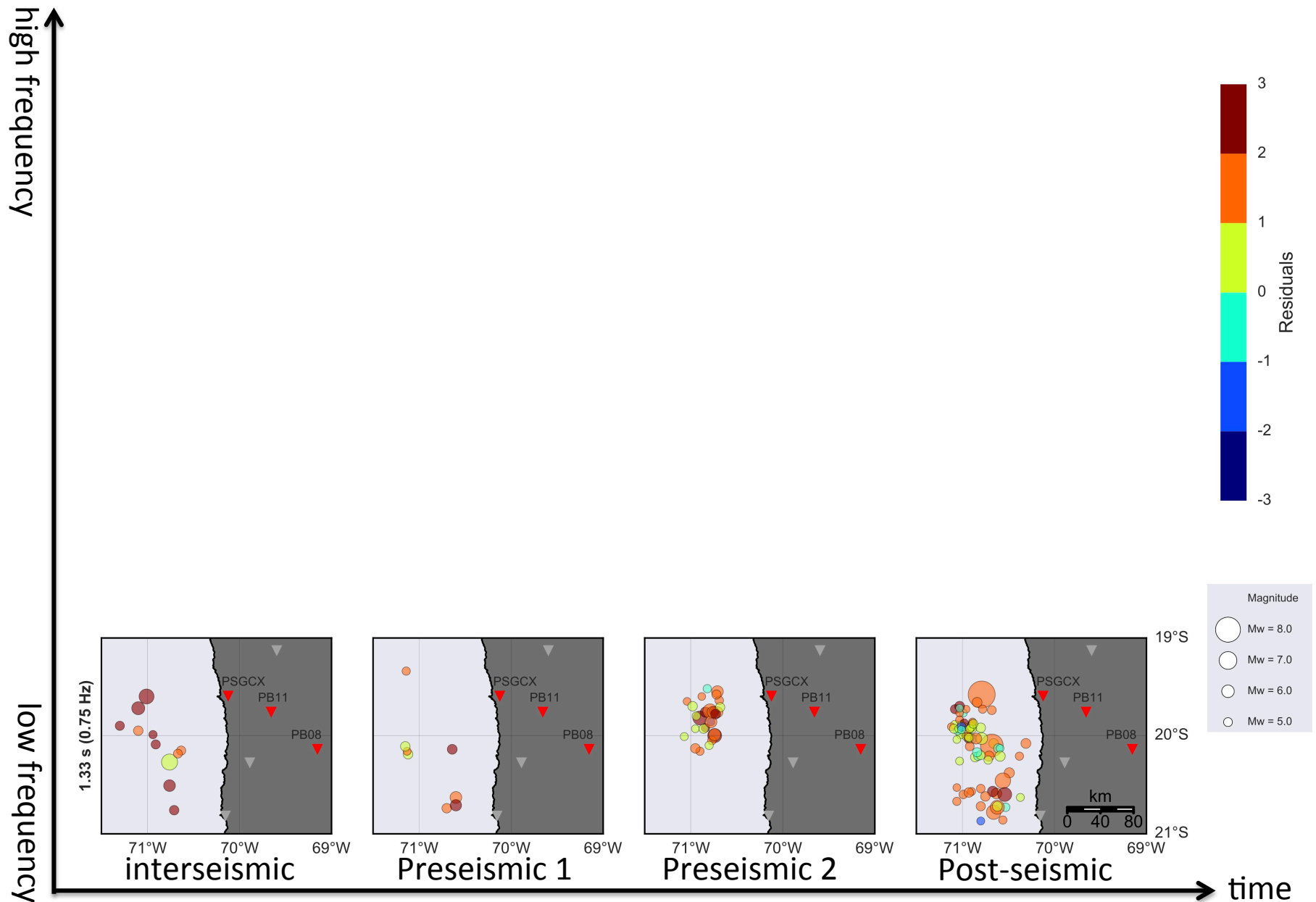


What signature in foreshock Frequency content?

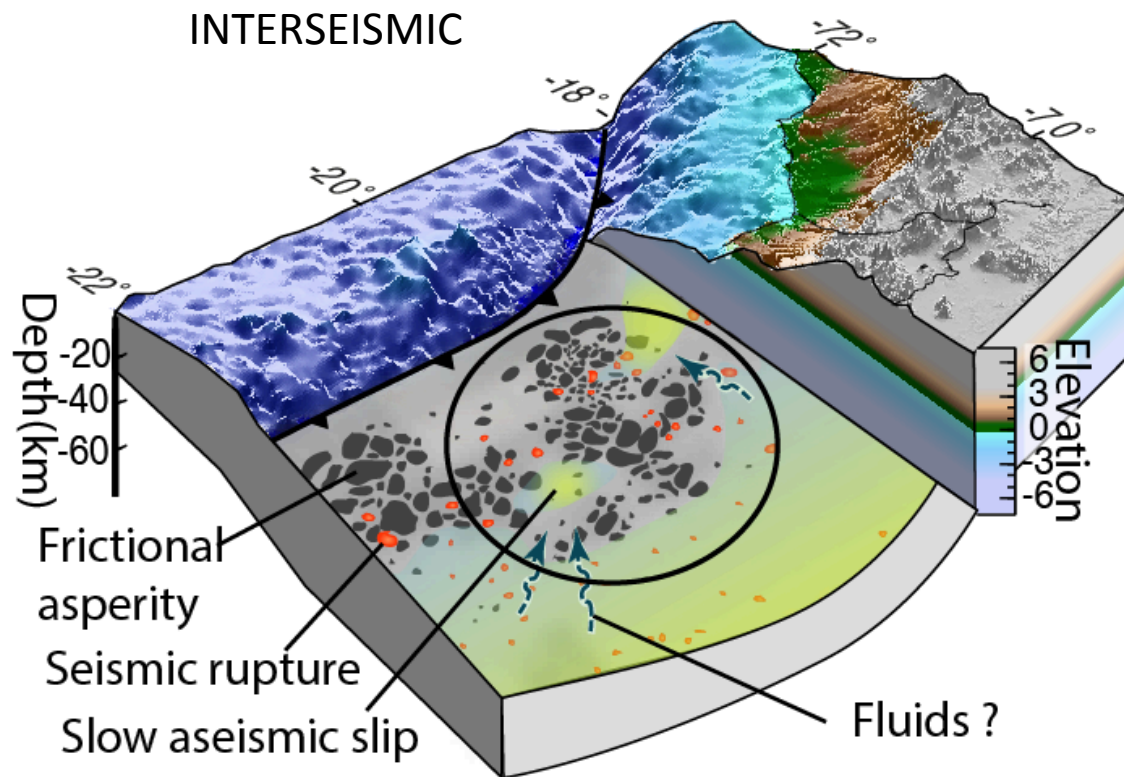
Residuals wrt GMPE (Ground Motion Prediction Equations)

Socquet et al., GRL 2017

Piña Valdes et al., BSSA 2018



Tentative interpretation

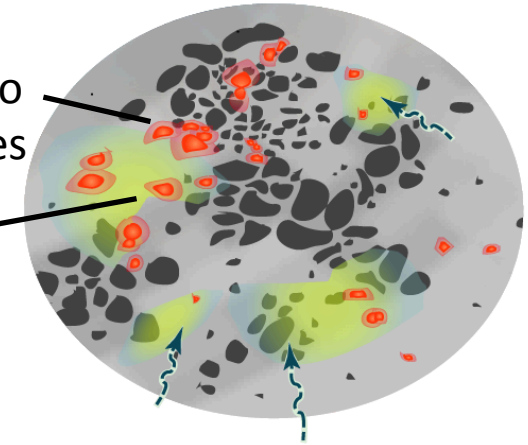


Tentative interpretation

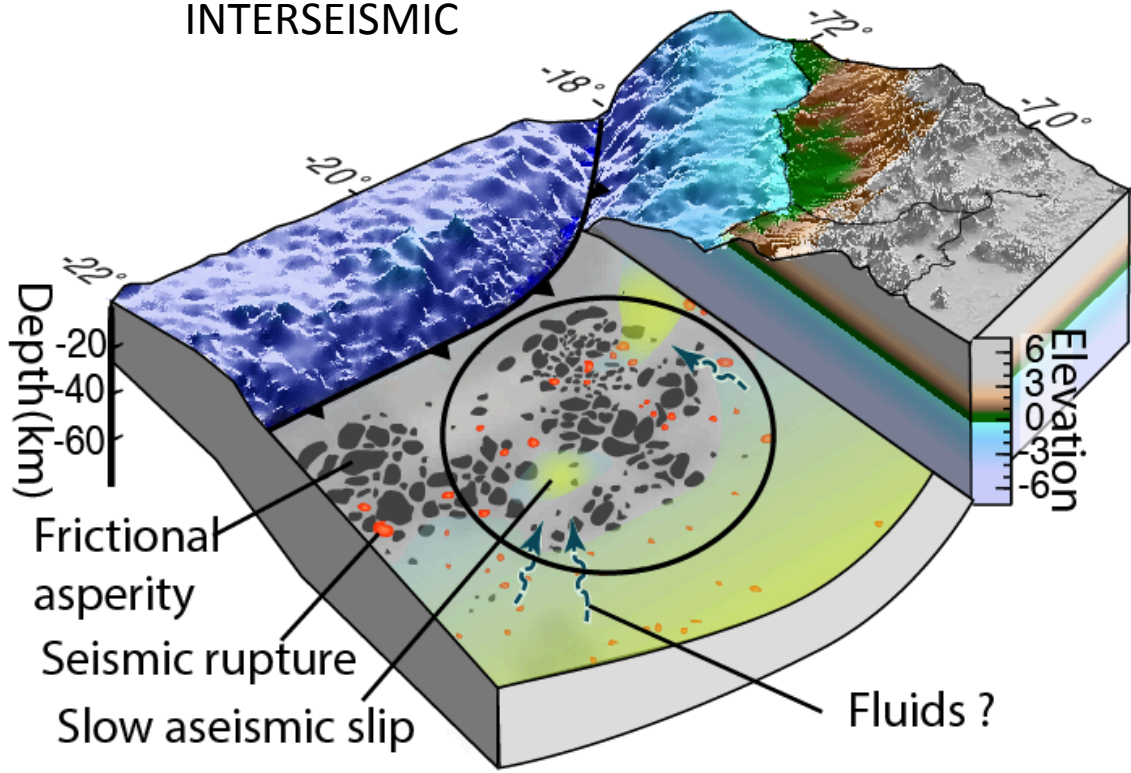
Seismic ruptures start to propagate into metastable areas surrounding asperities

Slow aseismic slip

8-month PRE-SEISMIC



INTERSEISMIC



Frictional asperity

Seismic rupture

Slow aseismic slip

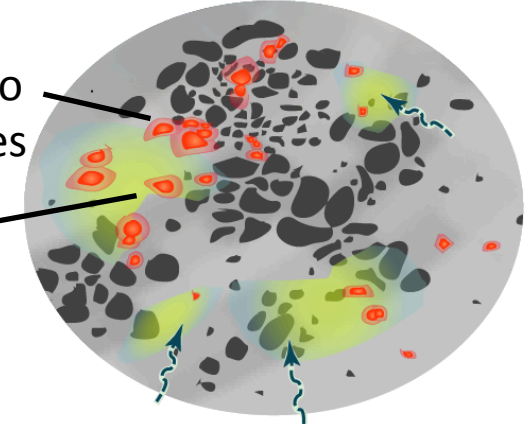
Fluids ?

Tentative interpretation

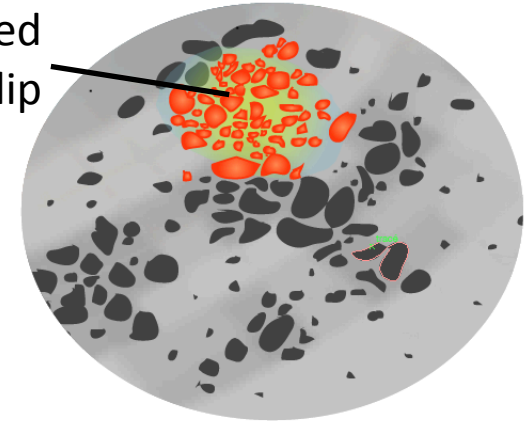
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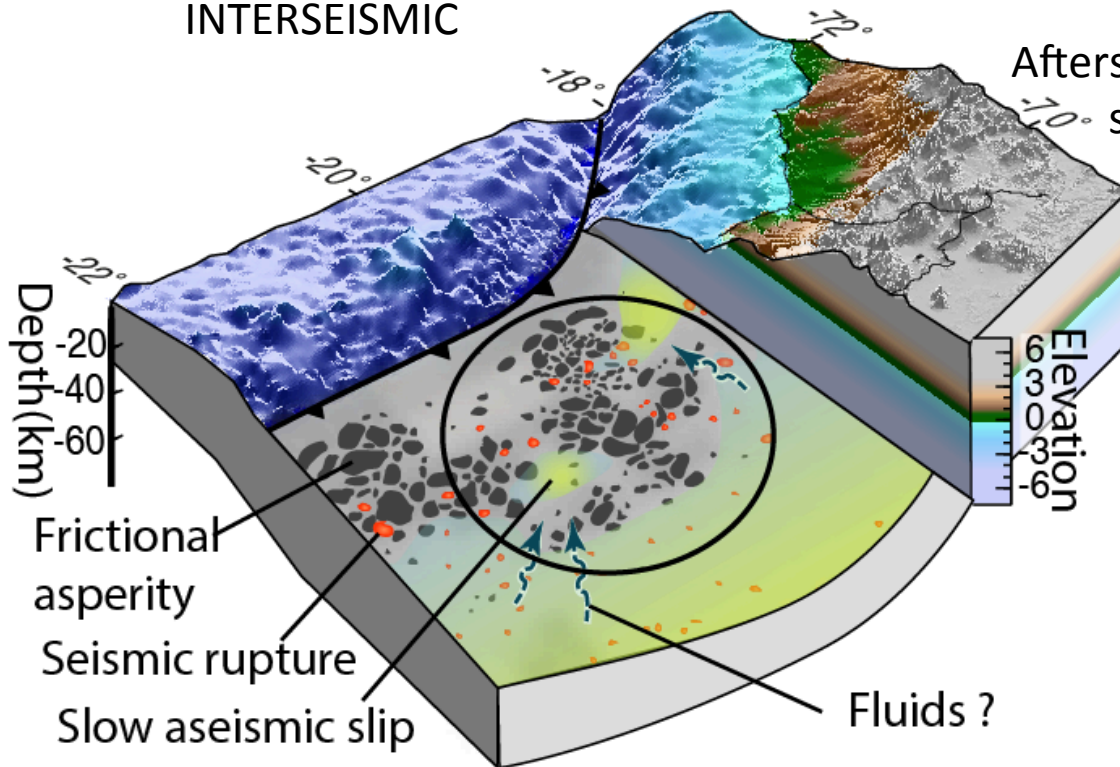
8-month PRE-SEISMIC



Aftershock cascade superimposed on slow slip



INTERSEISMIC

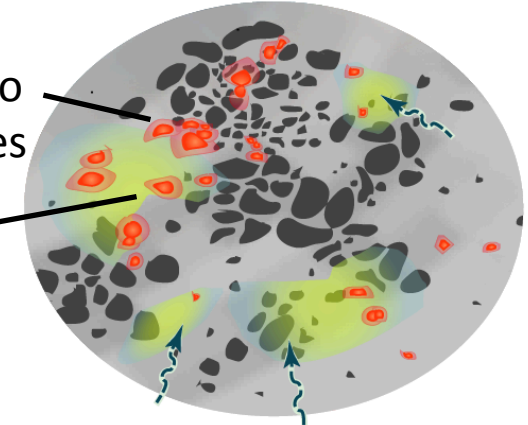


Tentative interpretation

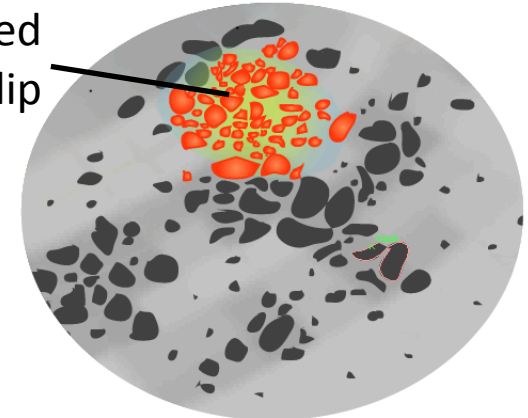
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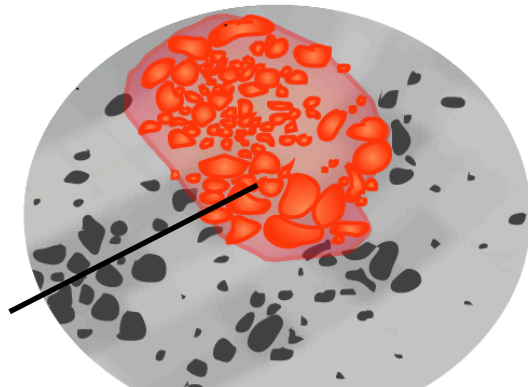
8-month PRE-SEISMIC



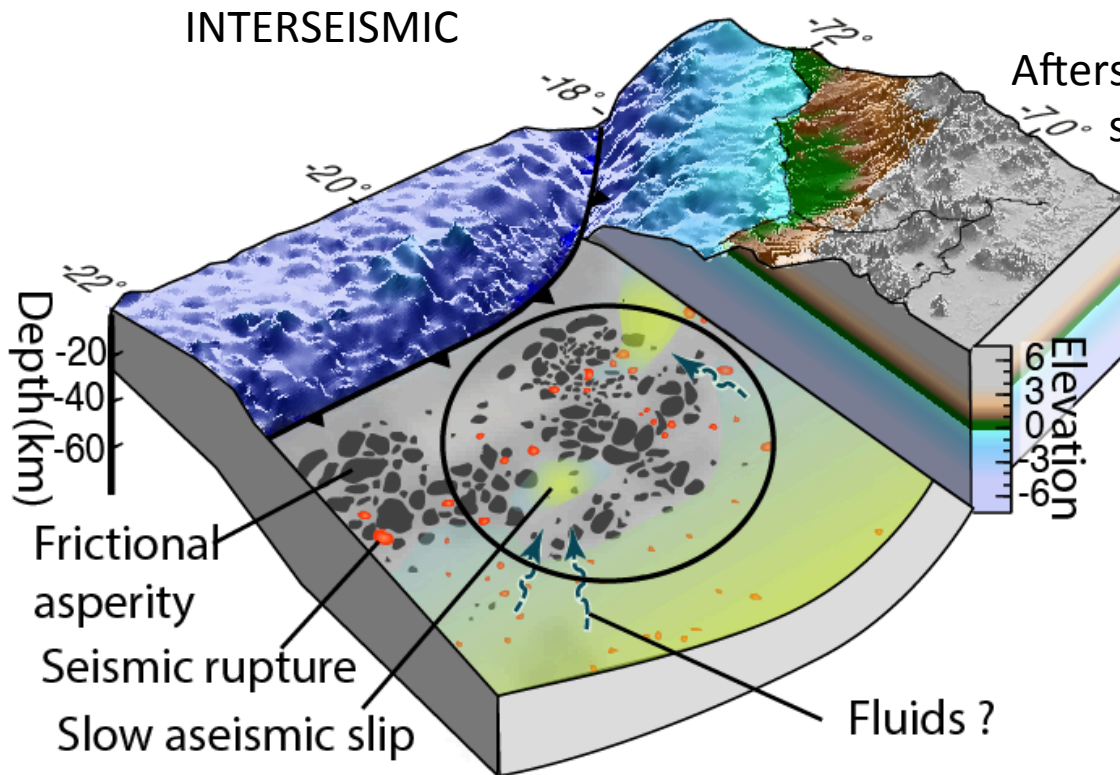
After Mw6.7 FORESHOCK
Aftershock cascade superimposed on slow slip



MAINSHOCK



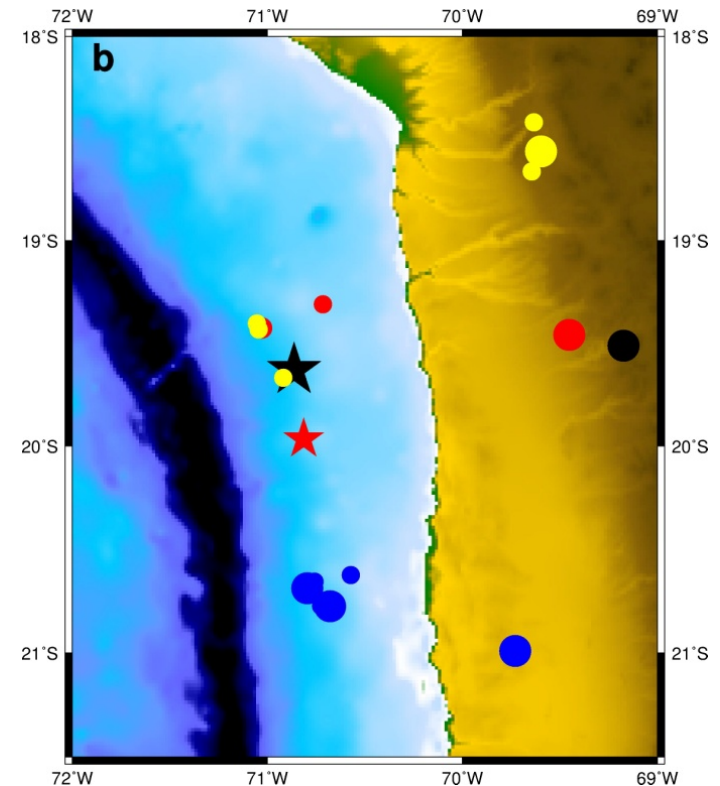
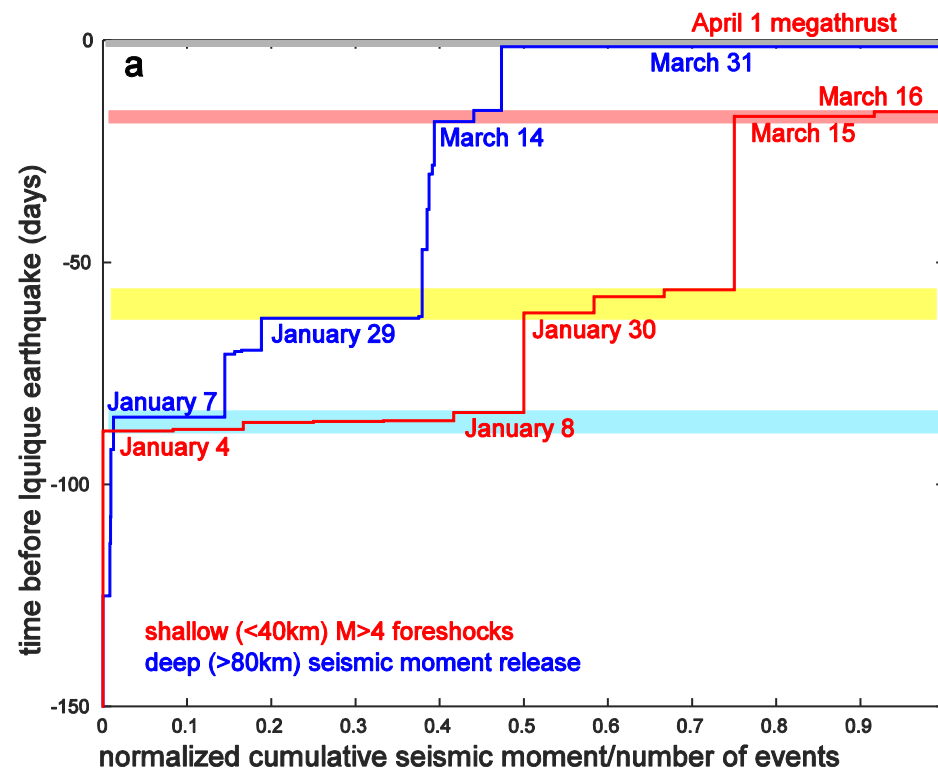
Socquet et al., GRL 2017



Mainshock ruptures a large portion of the subduction interface, propagating through metastable areas

But what is the mechanism that drives this slow slip acceleration?

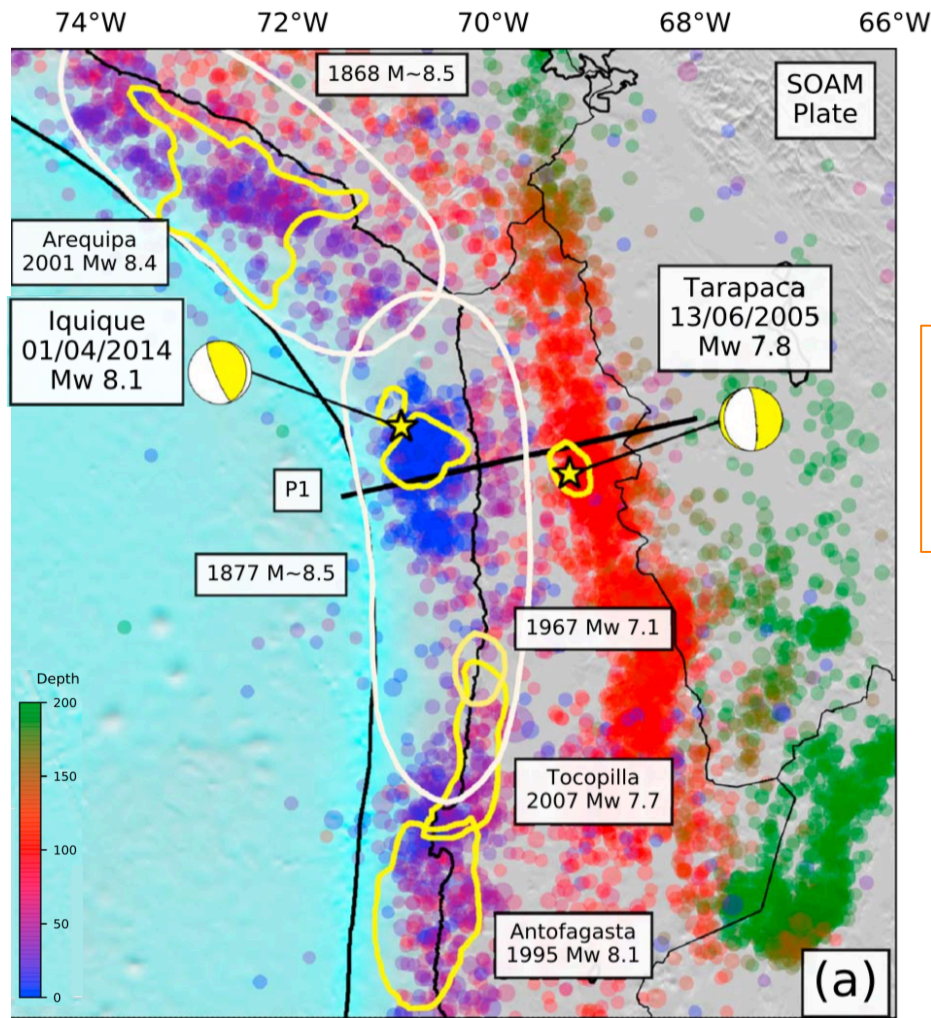
Intriguing observation: Synchronized deep and shallow seismicity suggests a slab plunge before Iquique quake



... but only studied for the 3-months before the megathrust

(Bouchon et al., 2016)

Any long-term interactions between deep and shallow seismicity?



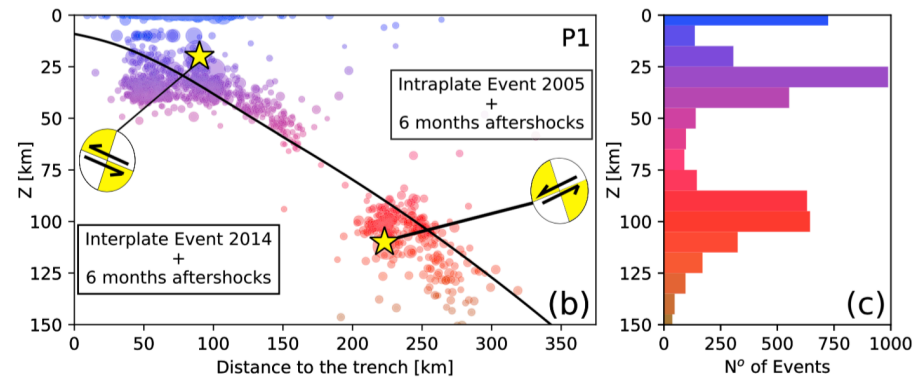
Seismic gap loaded by:

Interface Earthquakes

Intermediate Depth Earthquake

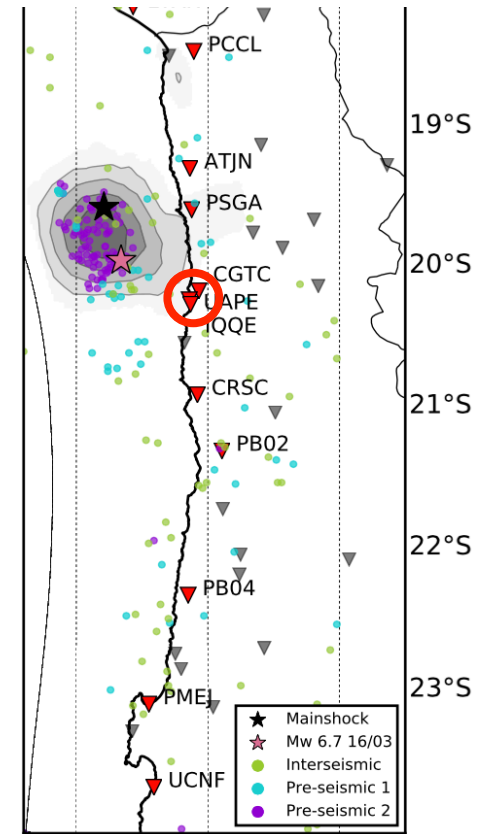
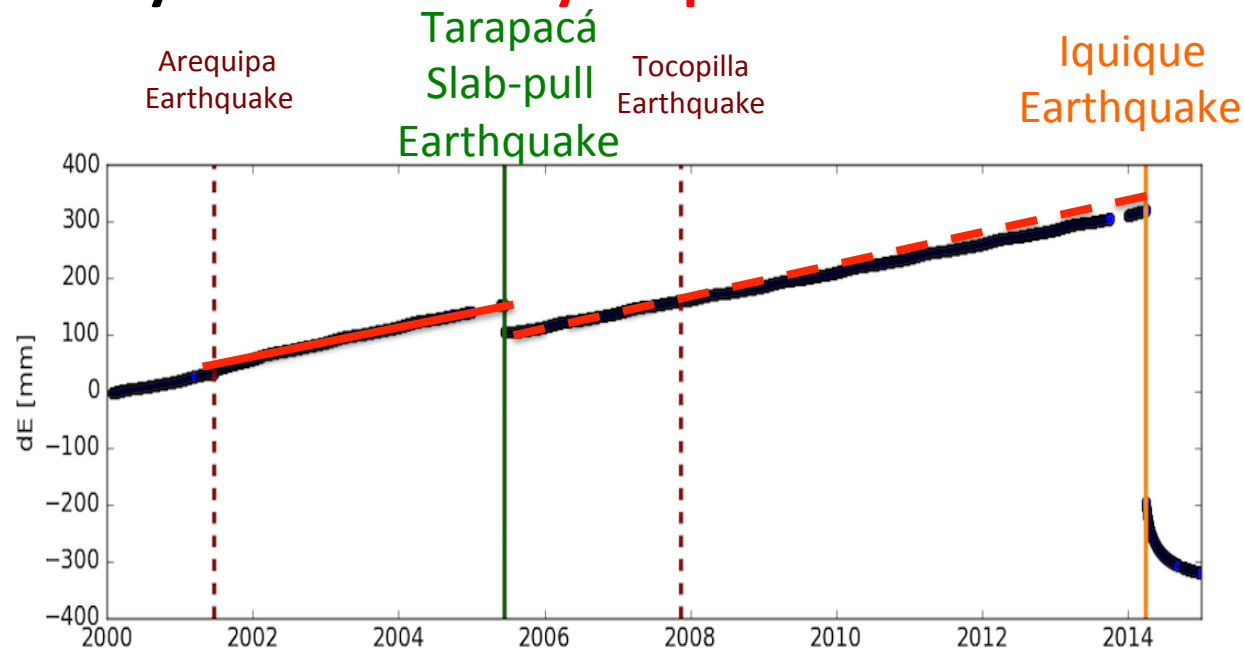
Mw 8.1 Antofagasta (1995)
Mw 8.4 Arequipa (2001)
Mw 7.7 Tocopilla (2007)
Mw 8.1 Iquique (2014)

Mw 7.8 Tarapaca (2005)

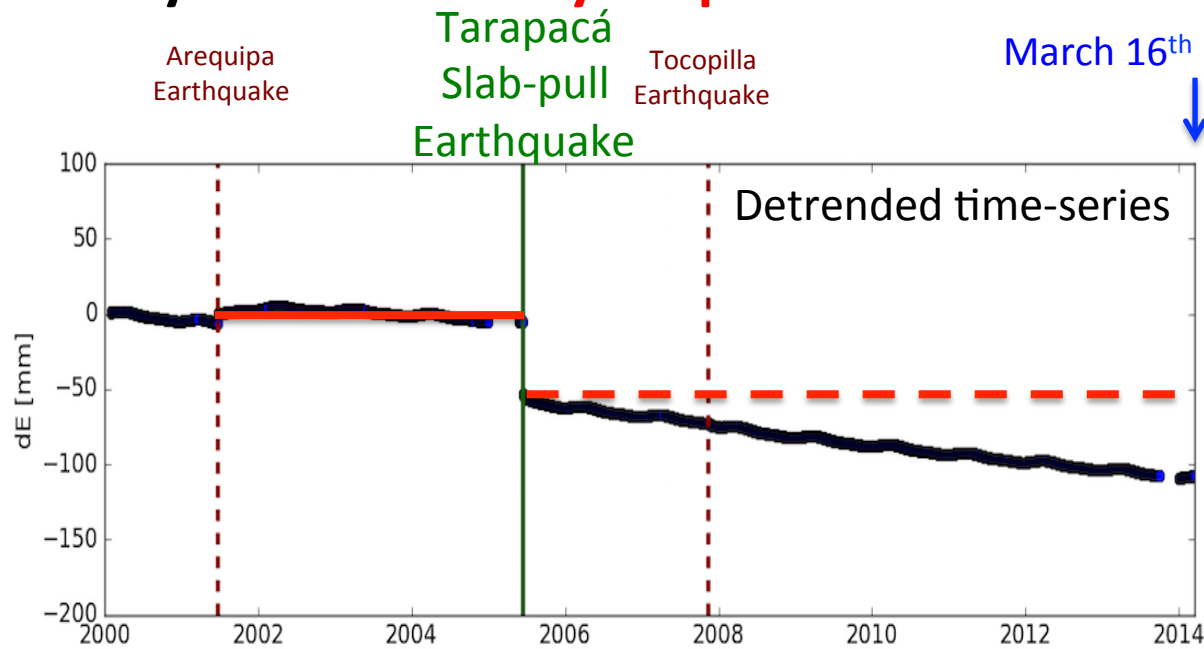


Is there any interaction between slab-pull and interface earthquakes (Tarapaca and Iquique)?

Seismic cycle seen in 15-year position time series of UAPE GPS station

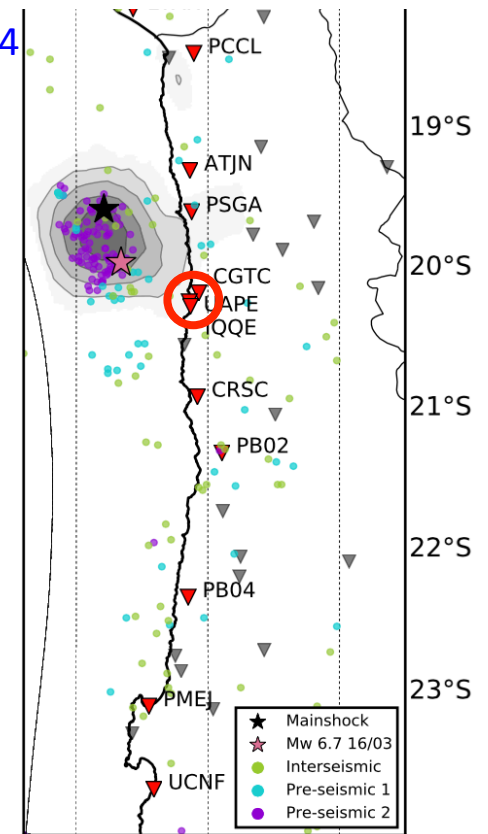


Seismic cycle seen in 15-year position time series of UAPE GPS station

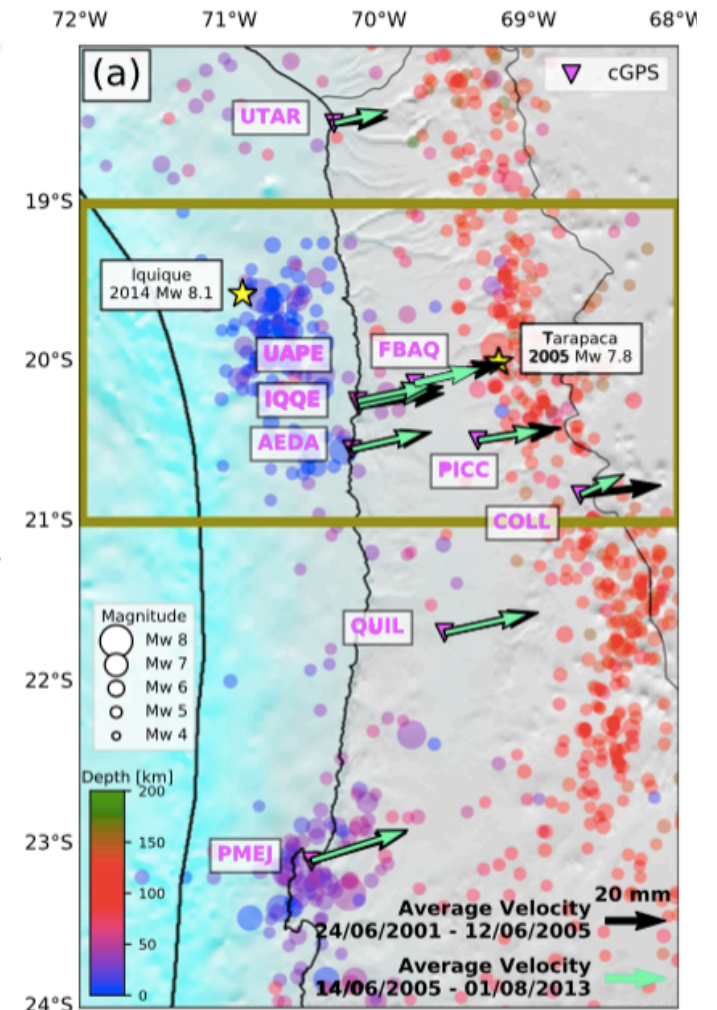
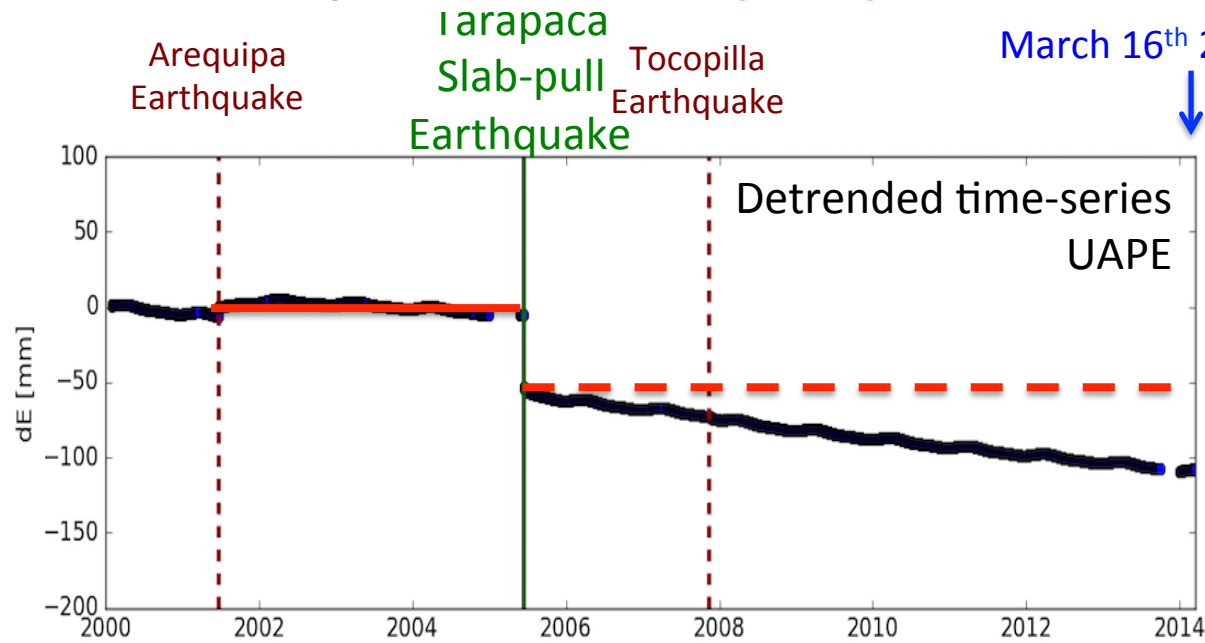


4mm/yr of difference

Significant velocity change between Tarapaca slab-pull and Iquique interface earthquake



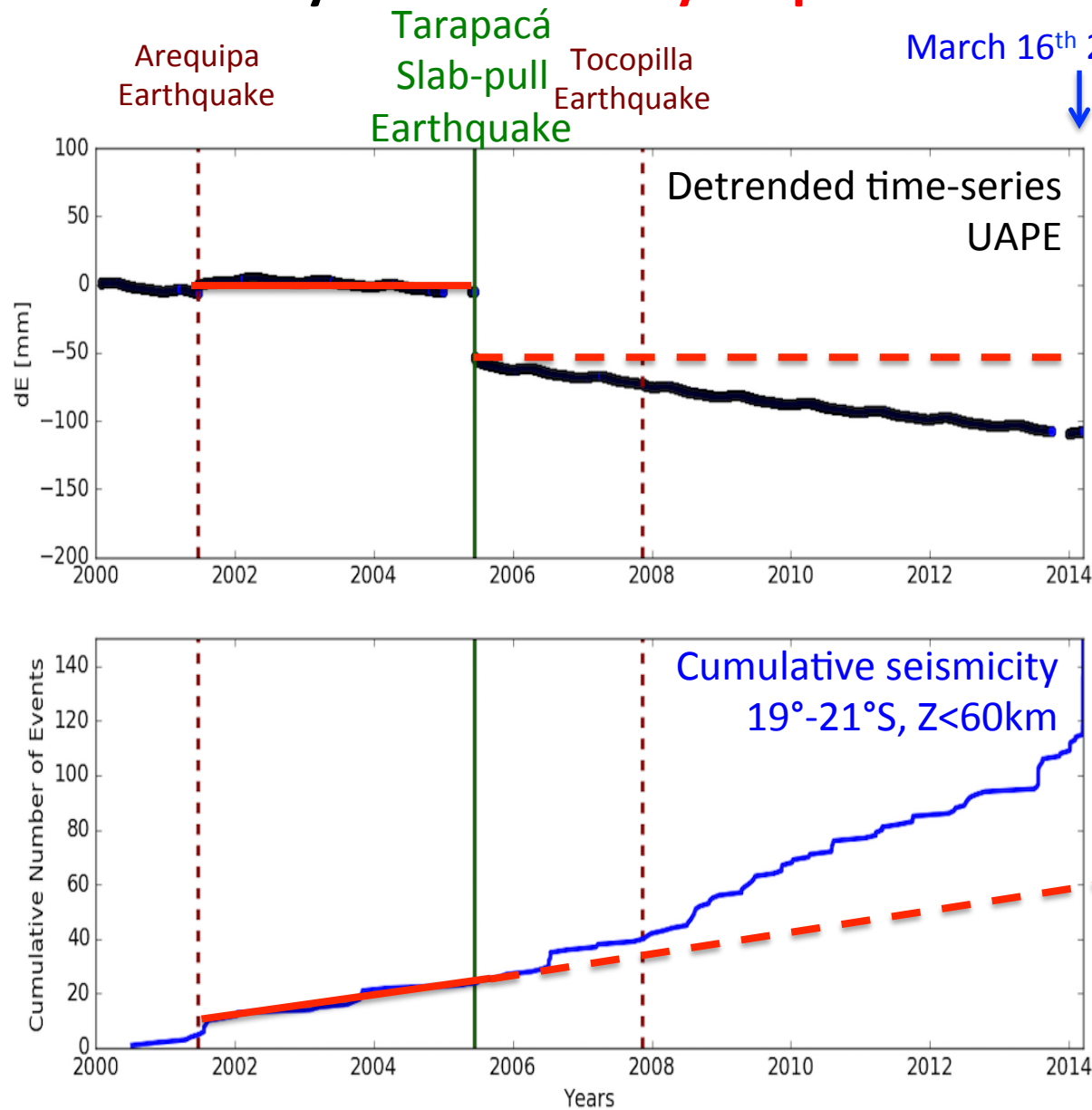
Seismic cycle seen in 15-year position time series of GPS stations



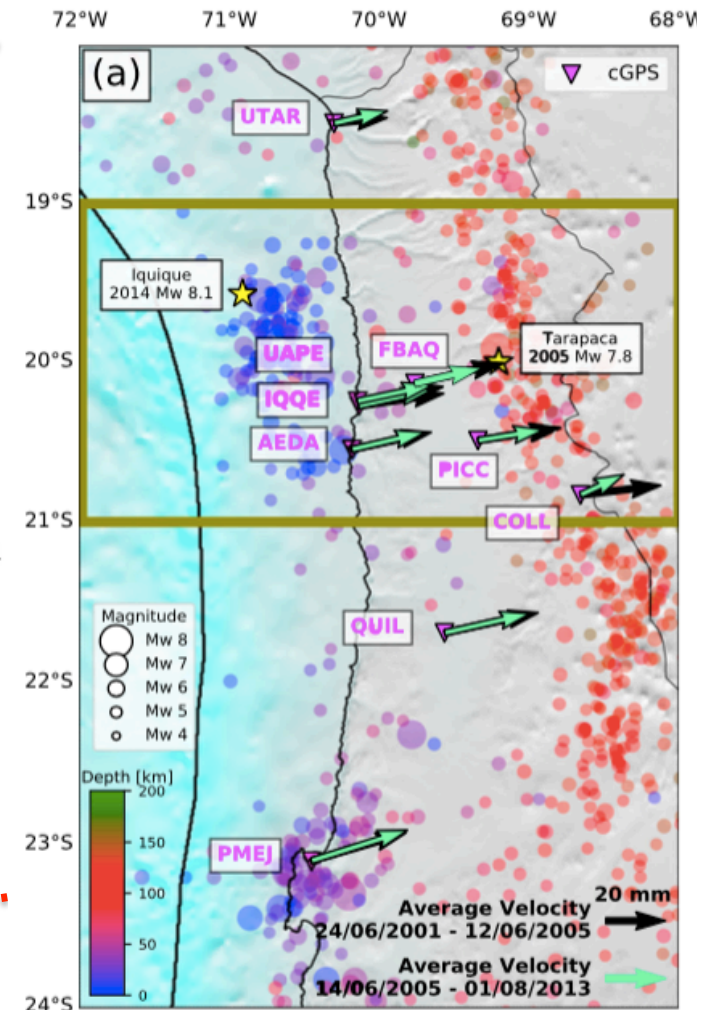
Significant velocity change between Tarapaca slab-pull and Iquique interface earthquake
 → Affects most stations in the area

Jara et al., GRL 2017

Seismic cycle seen in 15-year position and seismicity time series

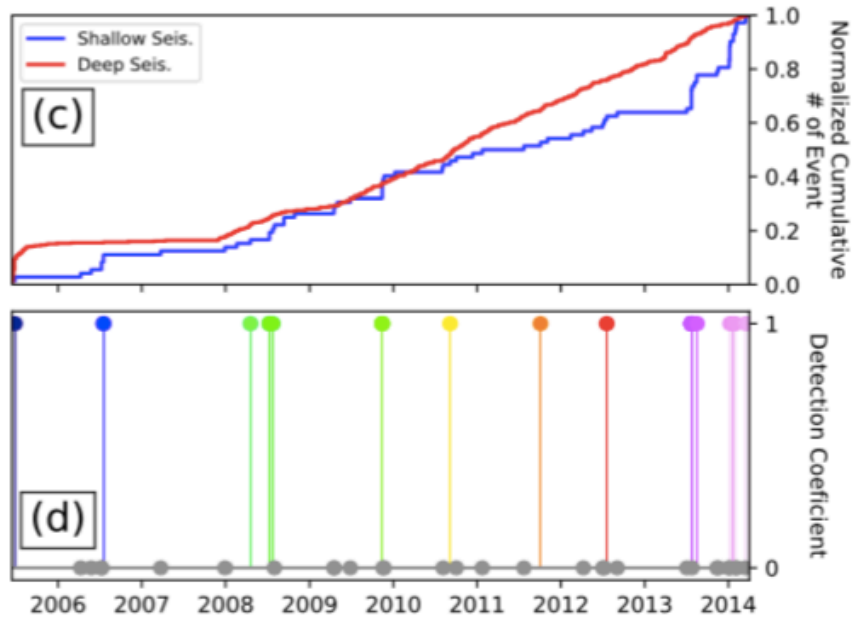


Shallow Seismicity increases after Tarapaca Earthquake



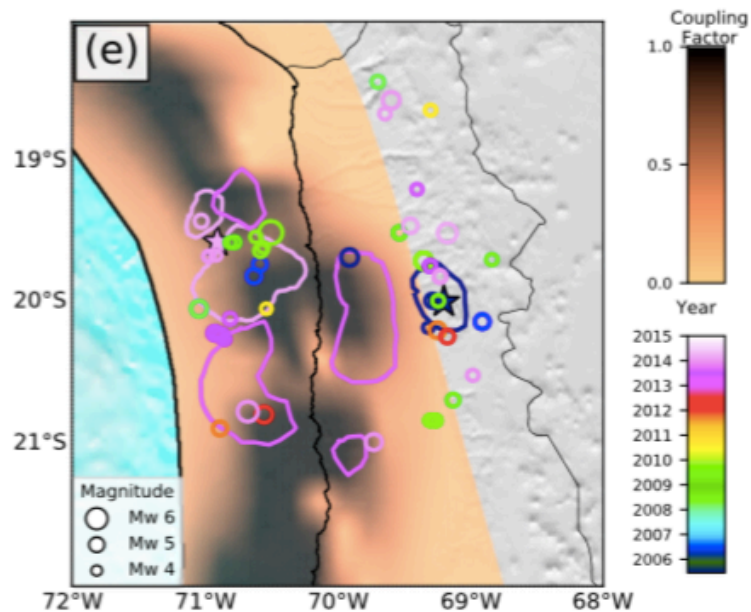
Significant velocity change between Tarapaca slab-pull and Iquique interface earthquake
 → Affects most stations in the area

Synchronization of deep and shallow earthquakes

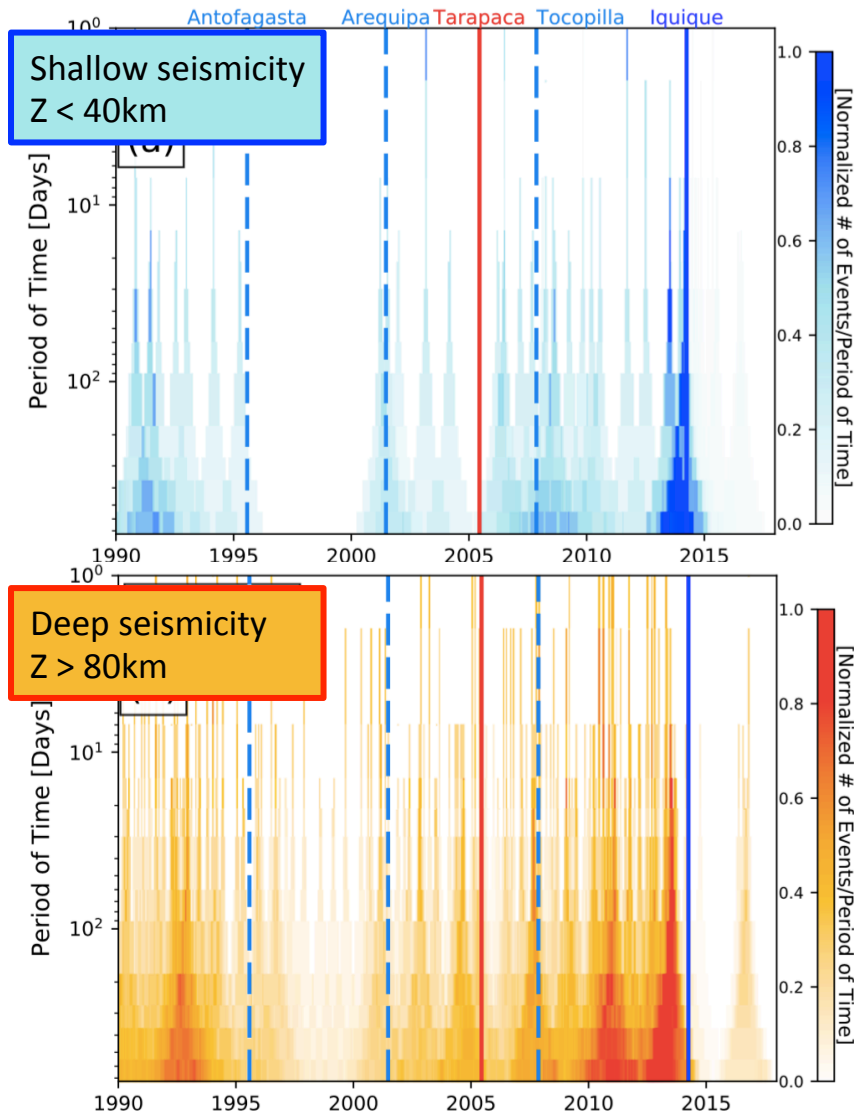


Number of couples of deep then shallow earthquakes within 2 day-windows

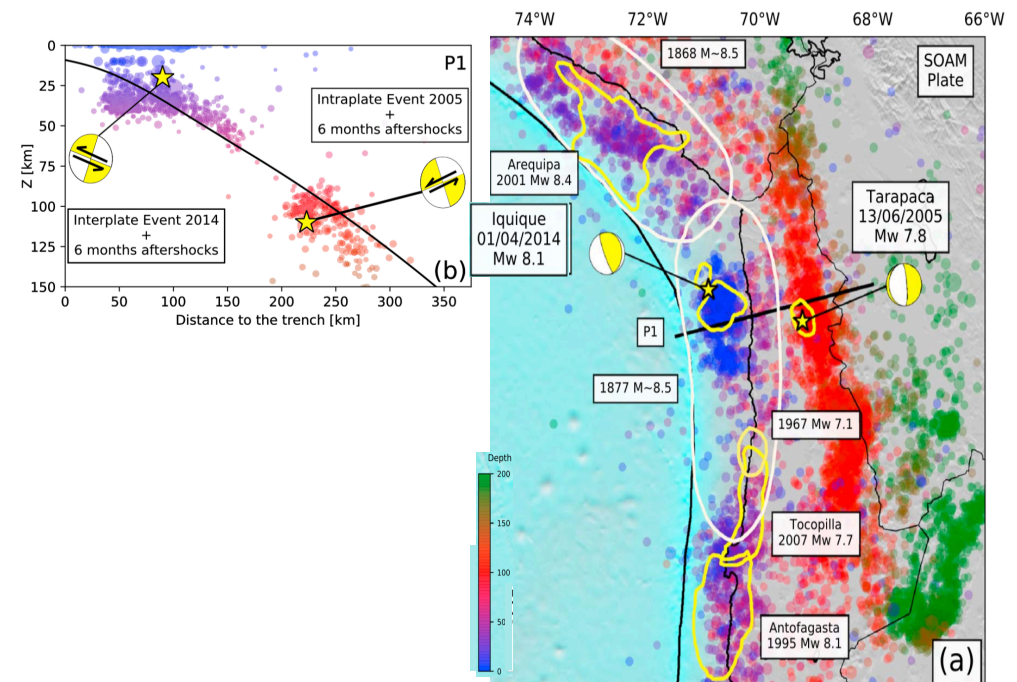
- After 2005 Slab pull: 16
- Before 2005 Slab pull: 0



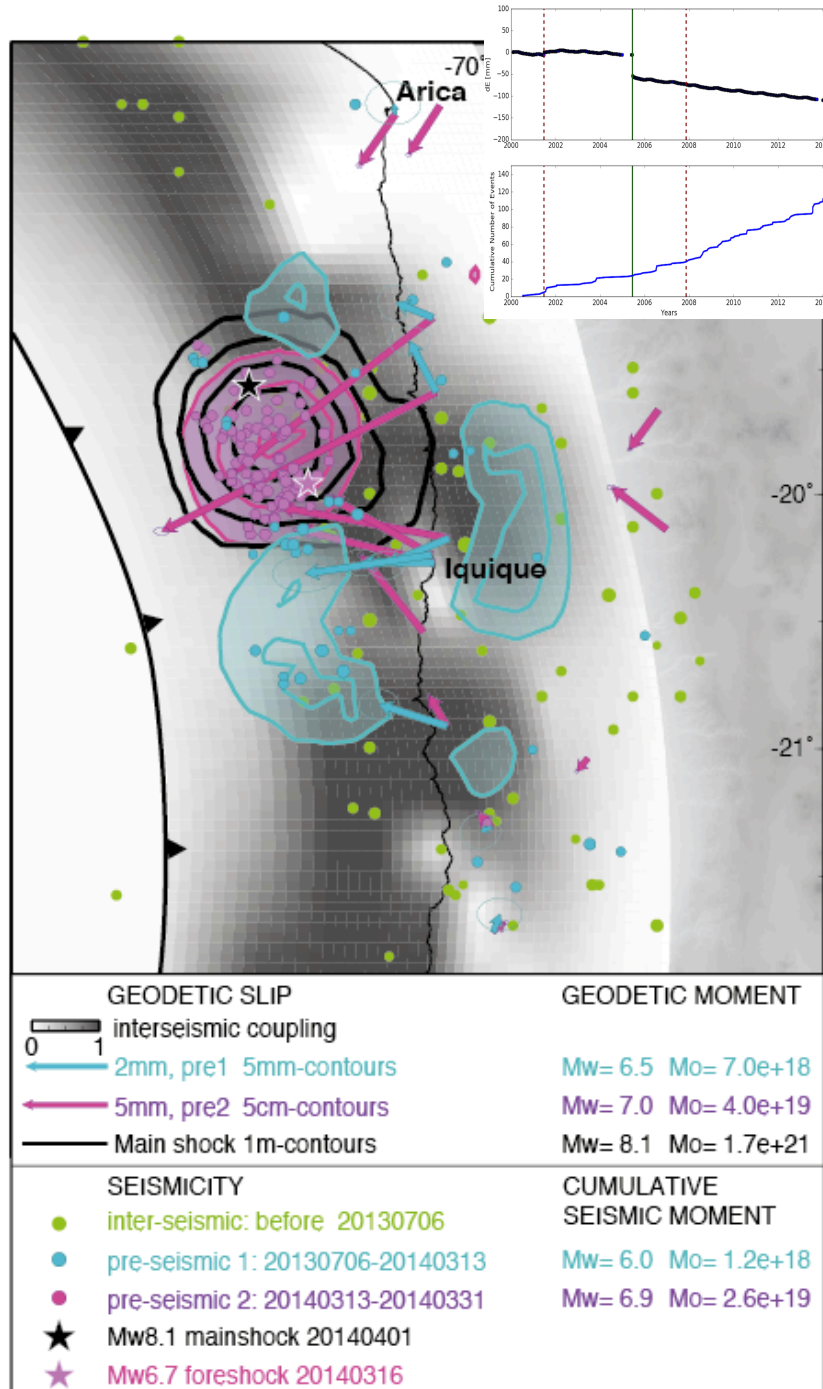
Evolution of background seismicity rate over 25 years



- Seismicity evolves by bursts
- Synchronous deep and shallow bursts
- 2014 megathrust is:
 - preceded by enhanced background seismic activity (deep and shallow)
 - followed by a period of quiescence (clamping?)



In summary....



9 years before 2014 Iquique earthquake, 2005 slab pull earthquake triggers:

- Decrease of eastward GPS velocities
 - Increase of deep & shallow seismicity rate
- Decoupling of interface
→ In response to slab tearing?

8 months before 2014 Iquique earthquake:

- Decrease of coastal velocities
 - Increase of seismicity
 - Decrease of b-value (Schurr et al.)
 - Decrease of high frequency radiations
- Mw6.5 slow slip, 80% aseismic change in earthquakes source (smoother)

15 days before Iquique EQ (after Mw6.7 foreshock)

- Abrupt increase of seismic activity
 - Strong deformation signal
- Mw7.0 slow slip, 35% aseismic