

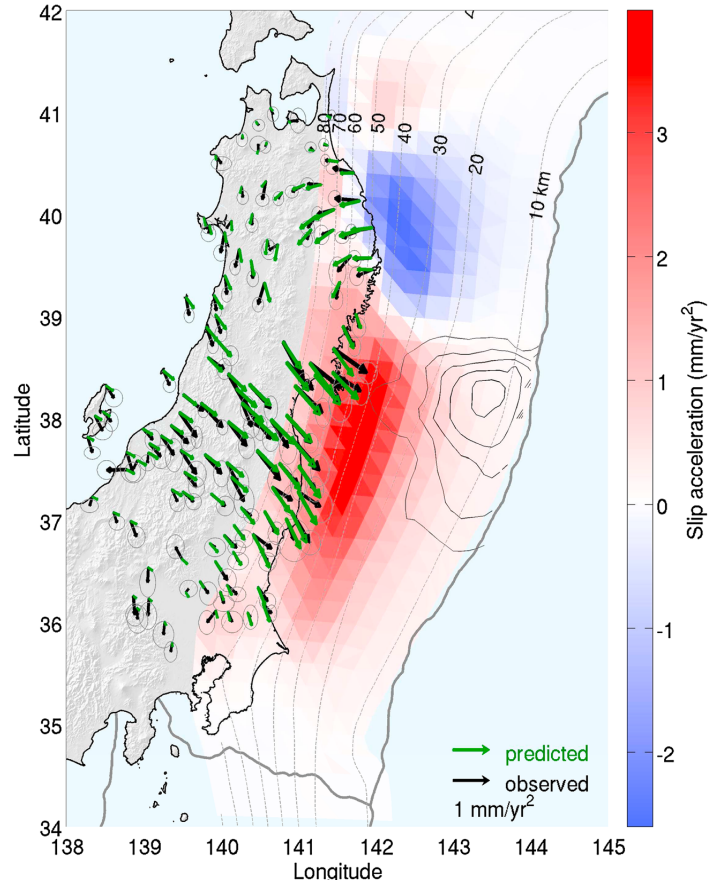
Revisiting the deformation transients before the 2011 Tohoku-Oki Megathrust Earthquake with GPS

Anne Socquet,

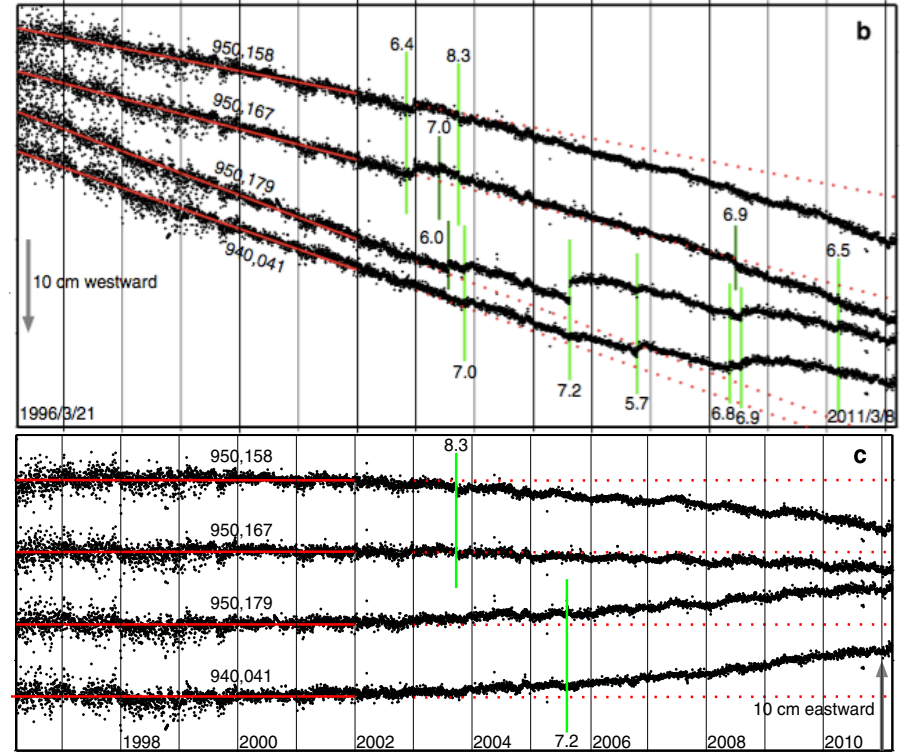
Lou Marill, David Marsan, Baptiste Rousset, Mathilde Radiguet,
Roland Burgmann, Nathalie Cotte, Michel Bouchon



CONTEXT : 2011 Tohoku EQ was preceded by 10-year transient deformation...

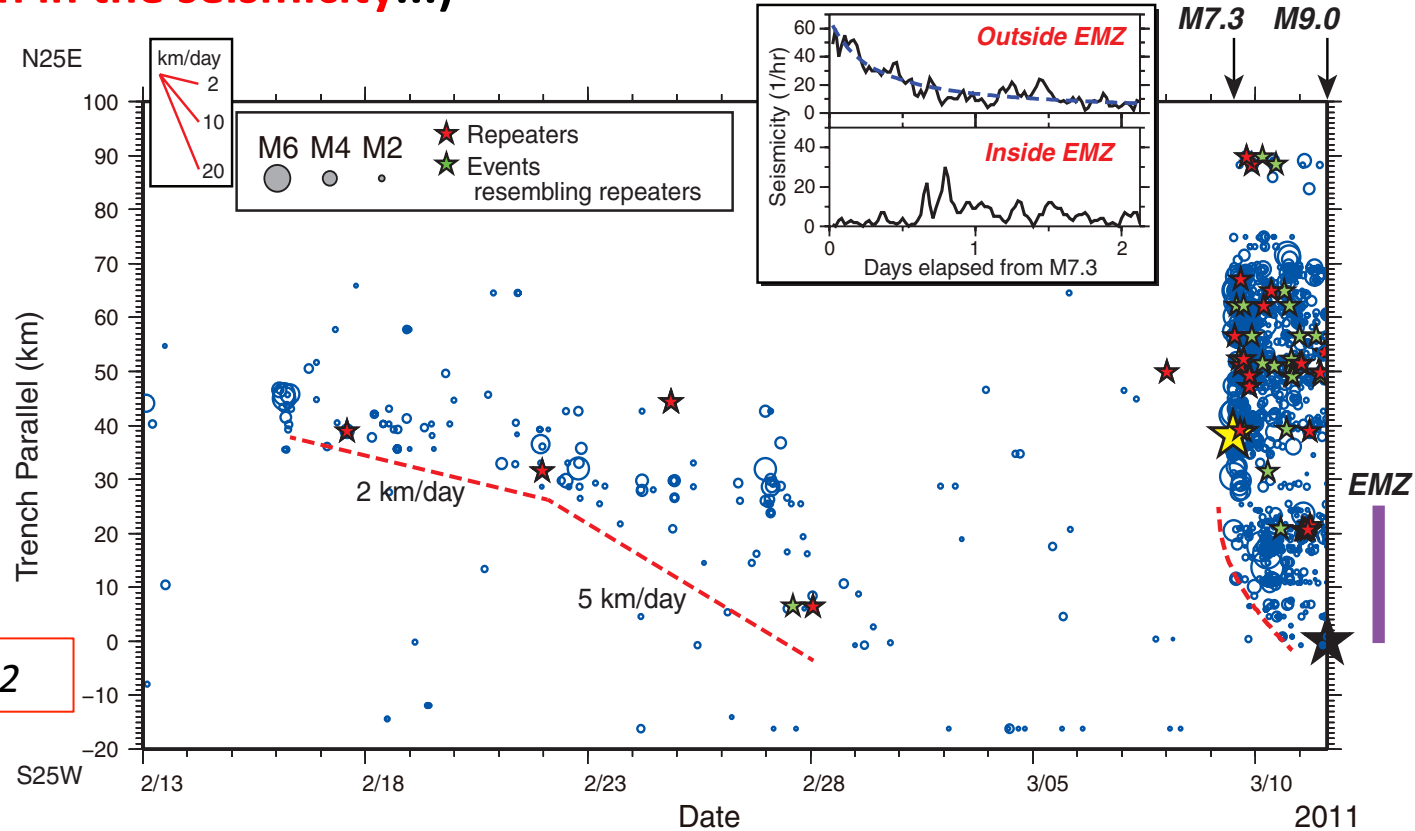


Seen in F3 solution from JMA



*Heki & Mitsui 2013; Mavrommatis et al., 2014;
Yokota and Koketsu et al., 2015*

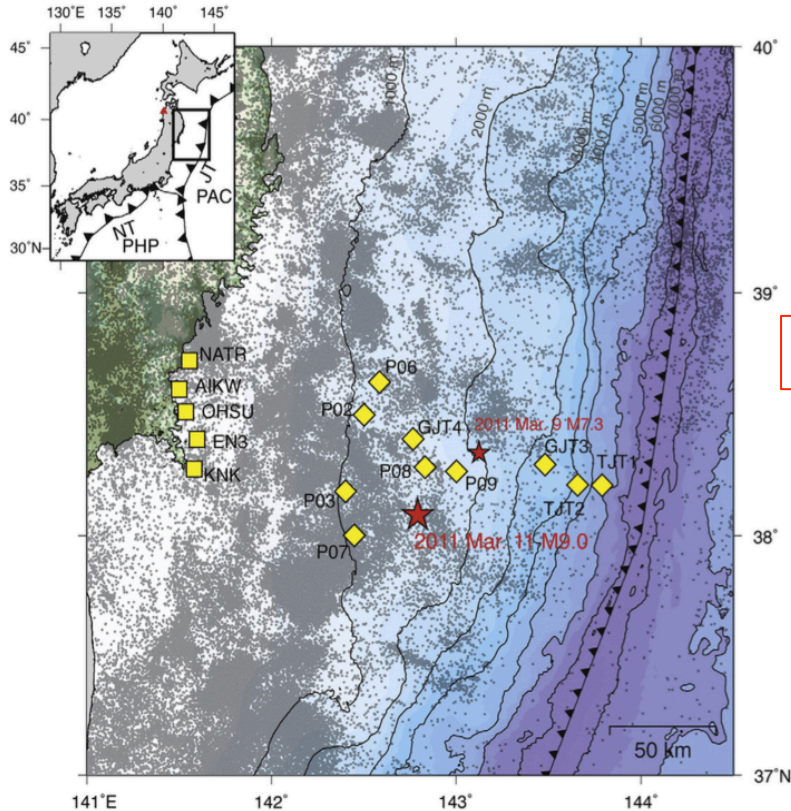
CONTEXT : 2011 Tohoku EQ was preceded by 10-year transient deformation...
... followed by a short-term (weeks / month) **slow slip**
(seen in the seismicity...)



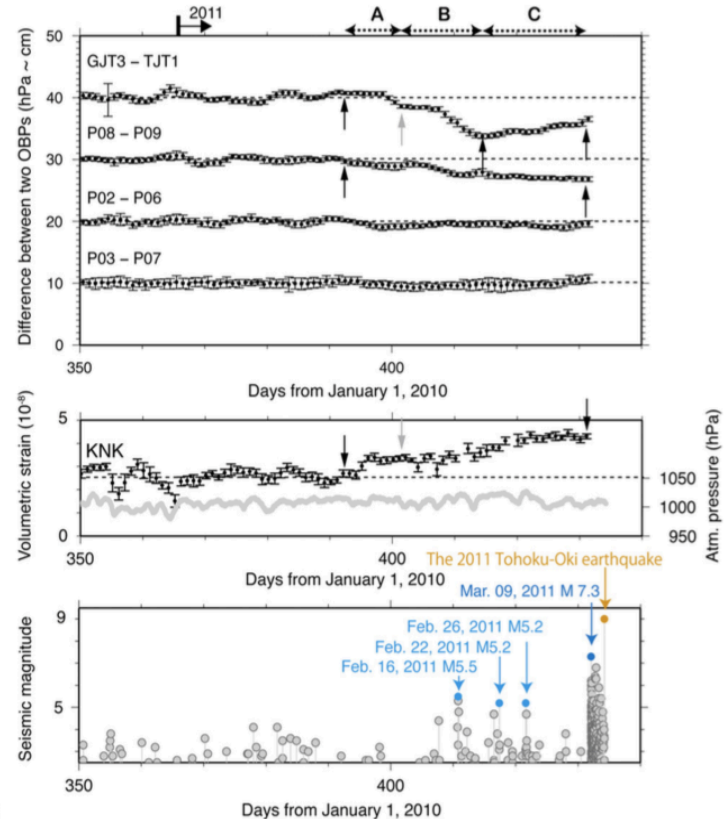
Kato et al, Science 2012

CONTEXT : 2011 Tohoku EQ was preceded by 10-year transient deformation...

... followed by a short-term (weeks / month) slow slip (seen in the seismicity & Ocean Bottom Pressure gauges)



Ito et al., 2013



1- Is the 10-year slow deformation before Tohoku also observed in independent GPS solution and analysis?

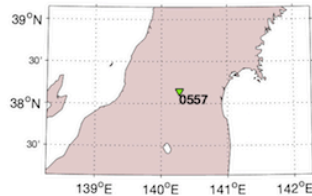
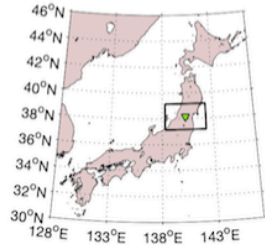
2- Is a short-term pre-seismic transient visible in GPS time series?

Complete, independent reanalysis of Japan GEONET GPS data

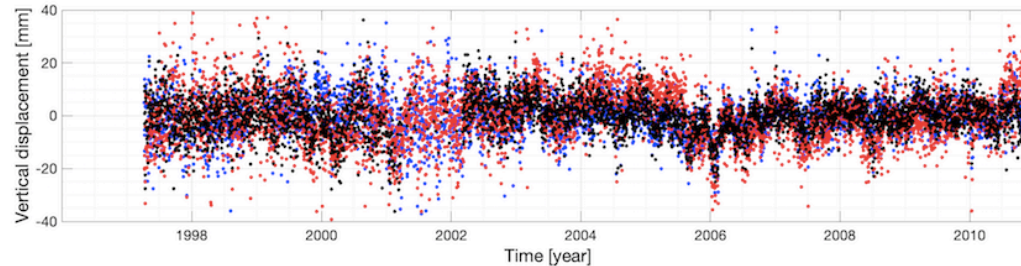
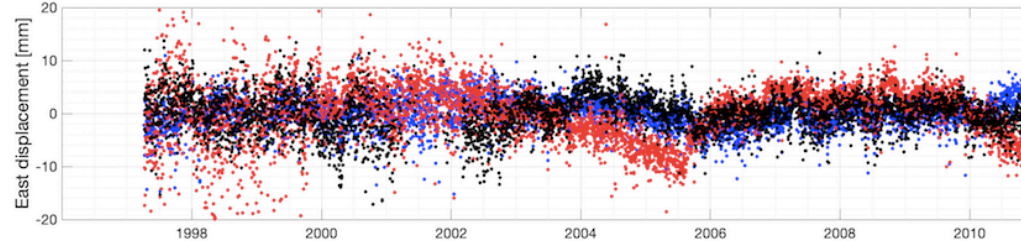
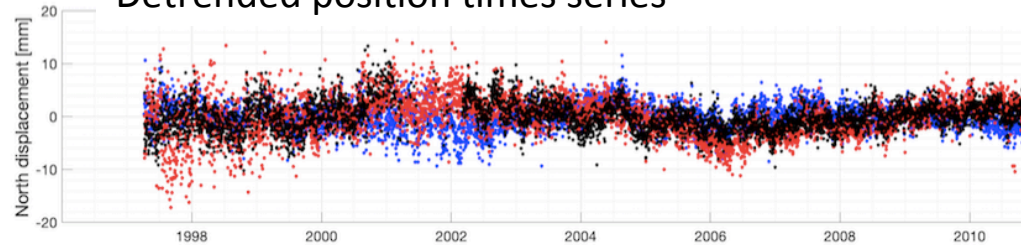
→ Full reprocessing with GAMIT and GIPSY software

→ How do they compare ?

Location of 0557 station



Detrended position times series



GAMIT

GipsyX

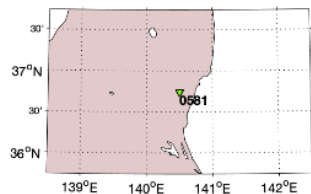
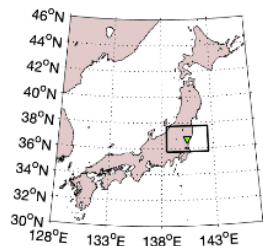
F3 JMA solution

Complete, independent reanalysis of Japan GEONET GPS data

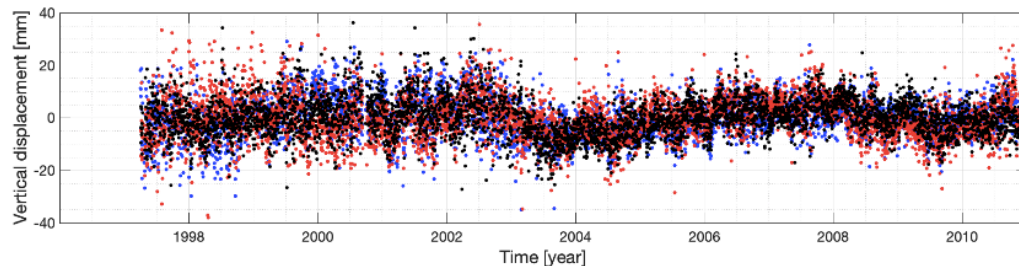
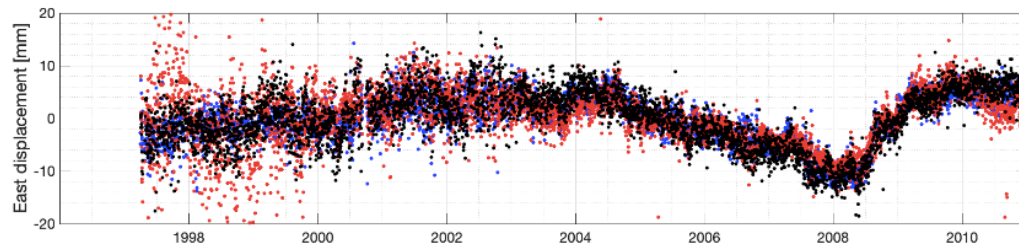
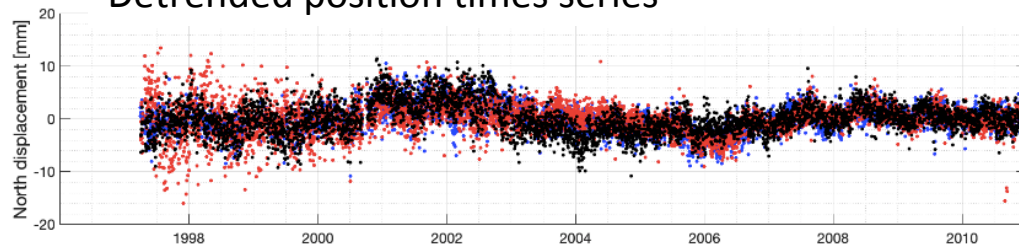
→ Full reprocessing with GAMIT and GIPSY software

→ How do they compare ?

Location of 0581 station



Detrended position times series



GAMIT
GipsyX
F3 JMA solution

Complete, independent reanalysis of Japan GEONET GPS data

Case 1 :
no acceleration term

→ Trajectory model

$$x(t) = x_R + v(t - t_R) + \cancel{\frac{1}{2}a(t - t_R)^2} + \sum_{k=1}^2 [s_k \sin(2k\pi(t - t_R)) + c_k \cos(2k\pi(t - t_R))] + \sum_{j=1}^{n_J} b_j H(t - t_j) + \sum_{s=1}^{n_S} d_s J(t - t_s) + \sum_{i=1}^{n_i} a_i \log\left(1 + \frac{t - t_i}{T_R}\right)$$

trend acceleration

seasonal
Position times series

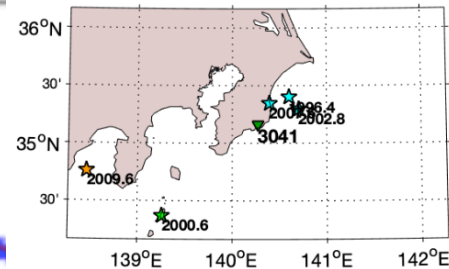
earthquakes

SSEs

post-seismic
(for Mw>7.2)

Raw + linear trajectory model

Residual



Complete, independent reanalysis of Japan GEONET GPS data

Case 2 :
with acceleration term

→ Trajectory model

$$x(t) = x_R + v(t - t_R) + \frac{1}{2}a(t - t_R)^2 + \sum_{k=1}^2 [s_k \sin(2k\pi(t - t_R)) + c_k \cos(2k\pi(t - t_R))] + \sum_{j=1}^{n_J} b_j H(t - t_j) + \sum_{s=1}^{n_S} d_s J(t - t_s) + \sum_{i=1}^{n_i} a_i \log\left(1 + \frac{t - t_i}{T_R}\right)$$

trend acceleration

seasonal

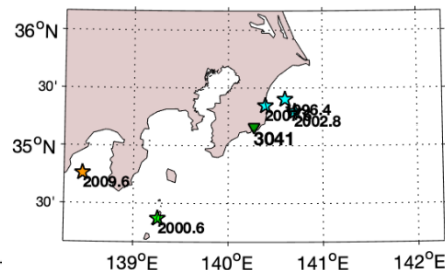
earthquakes

SSEs

post-seismic
(for Mw>7.2)

Position times series

Raw + quadratic trajectory model

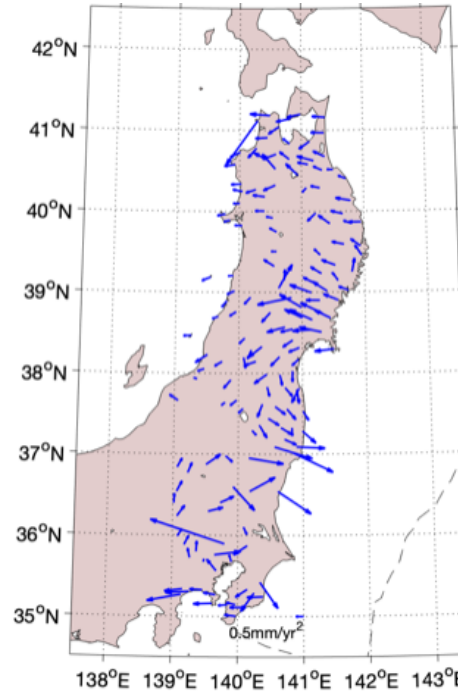


Residual

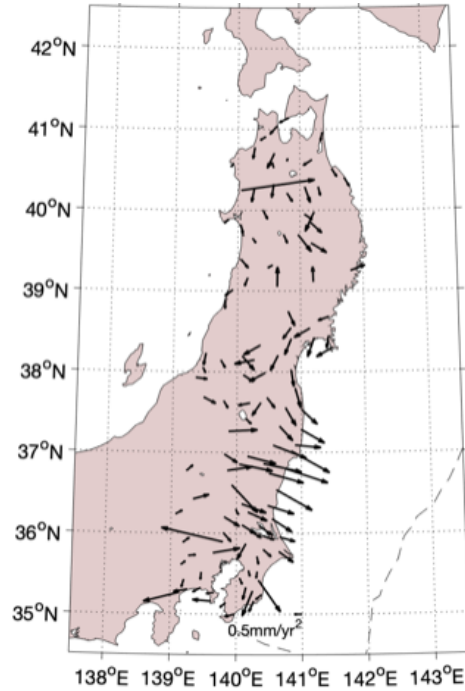
Accelerated displacement in Honshu (period 2006-2011)

Significant acceleration only

GAMIT solution



GipsyX solution



Long-term (*decades*) accelerated slip & seismicity before Tohoku earthquake (1996-2011)

Mavrommatis et al., 2014

Yokota and Koketsu et al., 2015

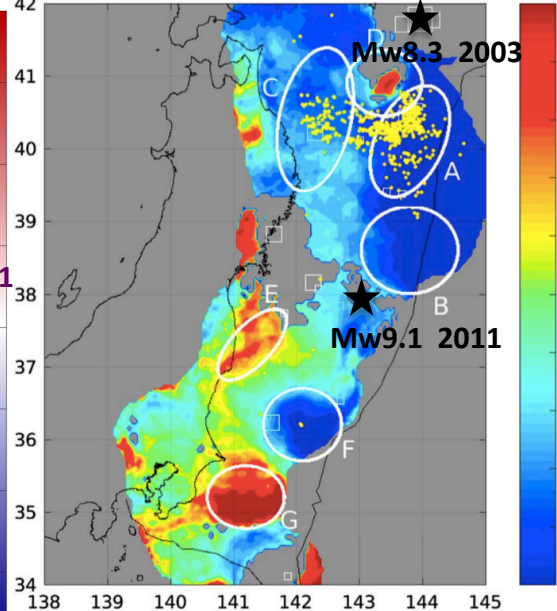
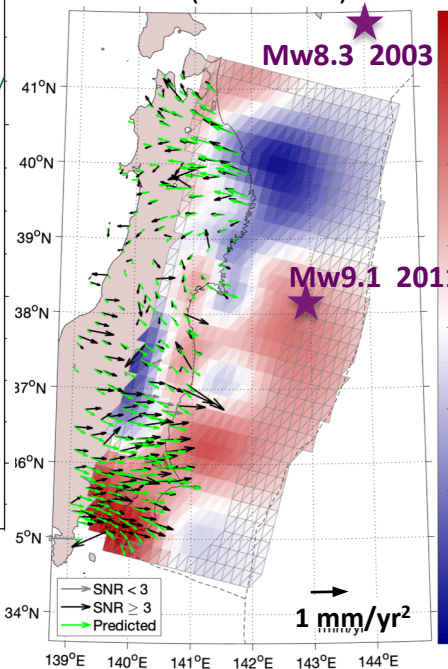
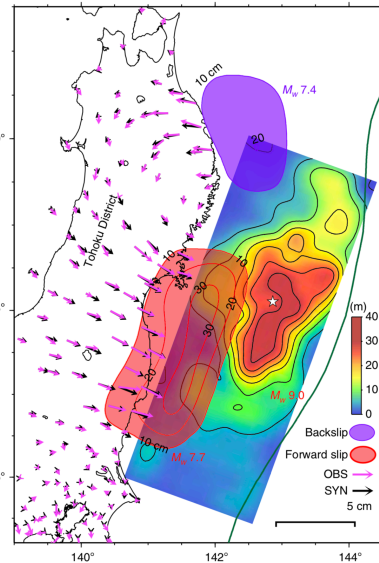
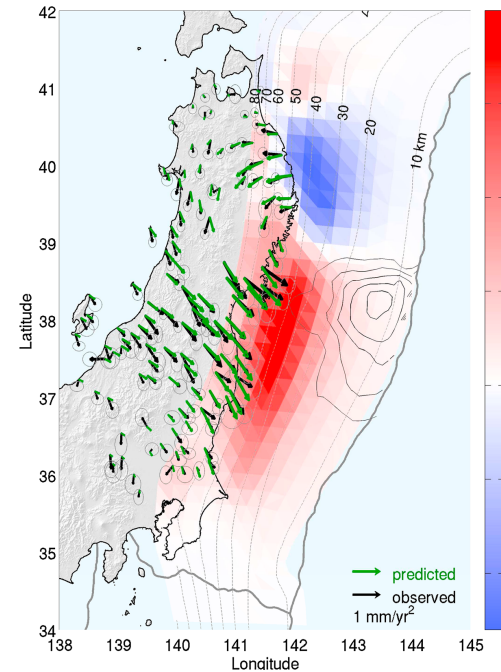
This study

F3 solution

GAMIT solution

Acceleration of background seismicity (1990-2011)
Marsan et al., JGR 2017

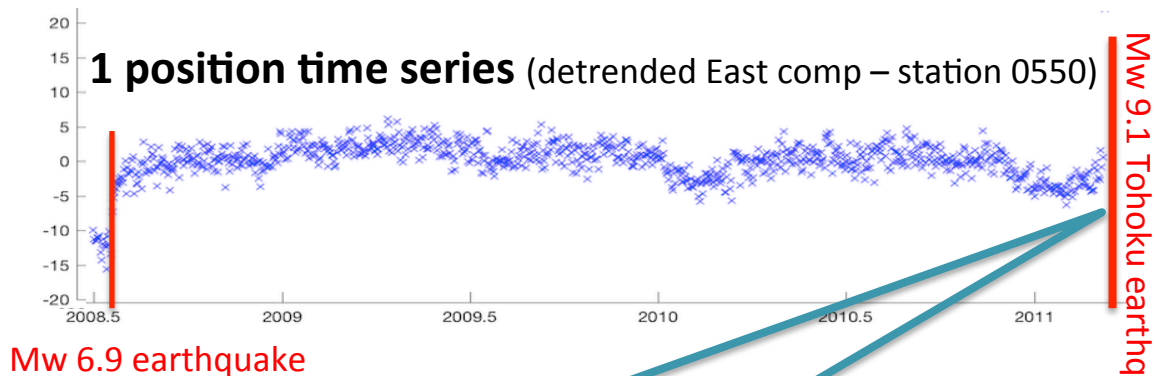
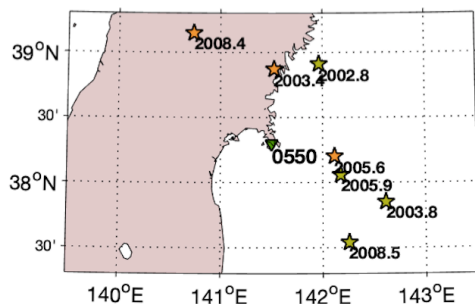
Slip acceleration
(1996-2011)



1- Is the 10-year slow deformation before Tohoku also observed in independent GPS solution and analysis?

2- Is a short-term pre-seismic transient visible in GPS time series?

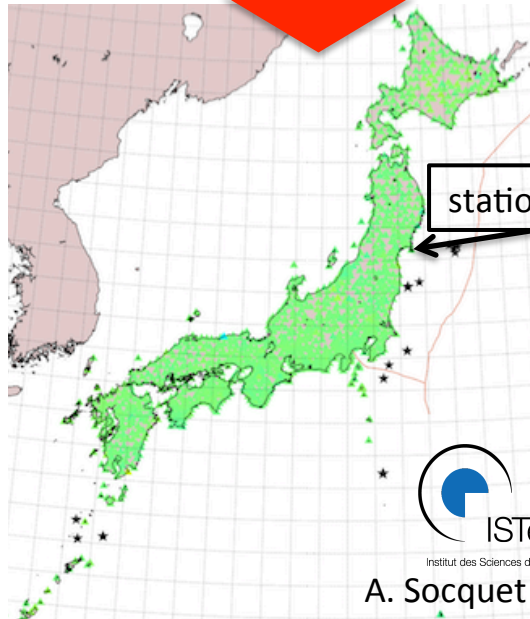
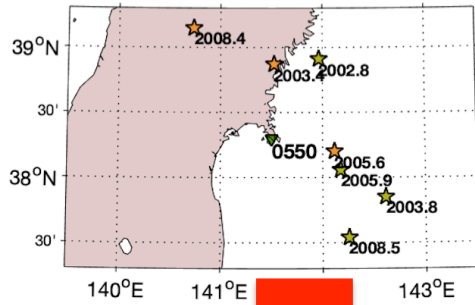
GEO-Net network analysis (3 years before Tohoku)



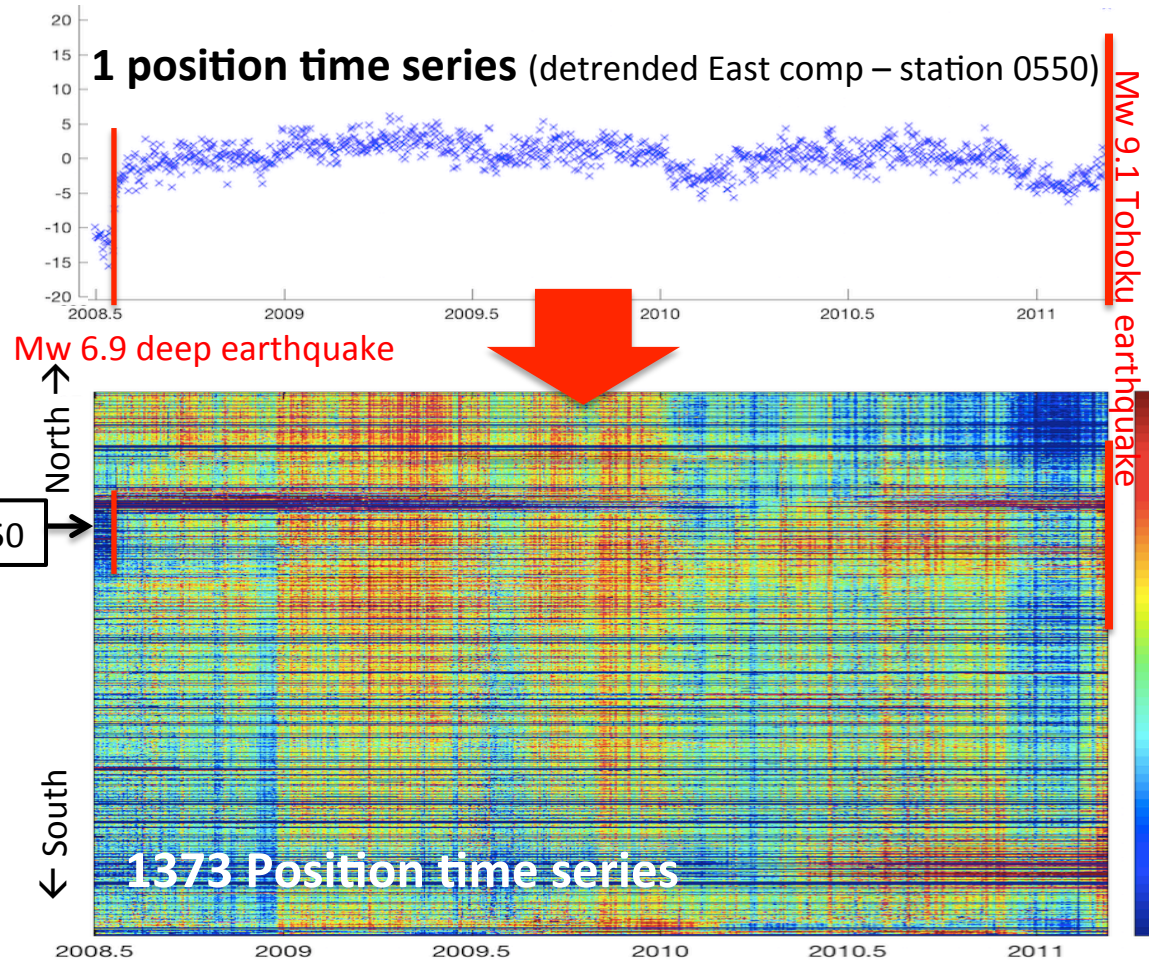
Is this an oscillating transient signal before Tohoku?

- Impossible to tell with a single station
- Network analysis is necessary...

GEO-Net network analysis (3 years before Tohoku)



ISTerre
Institut des Sciences de la Terre
A. Socquet et al.

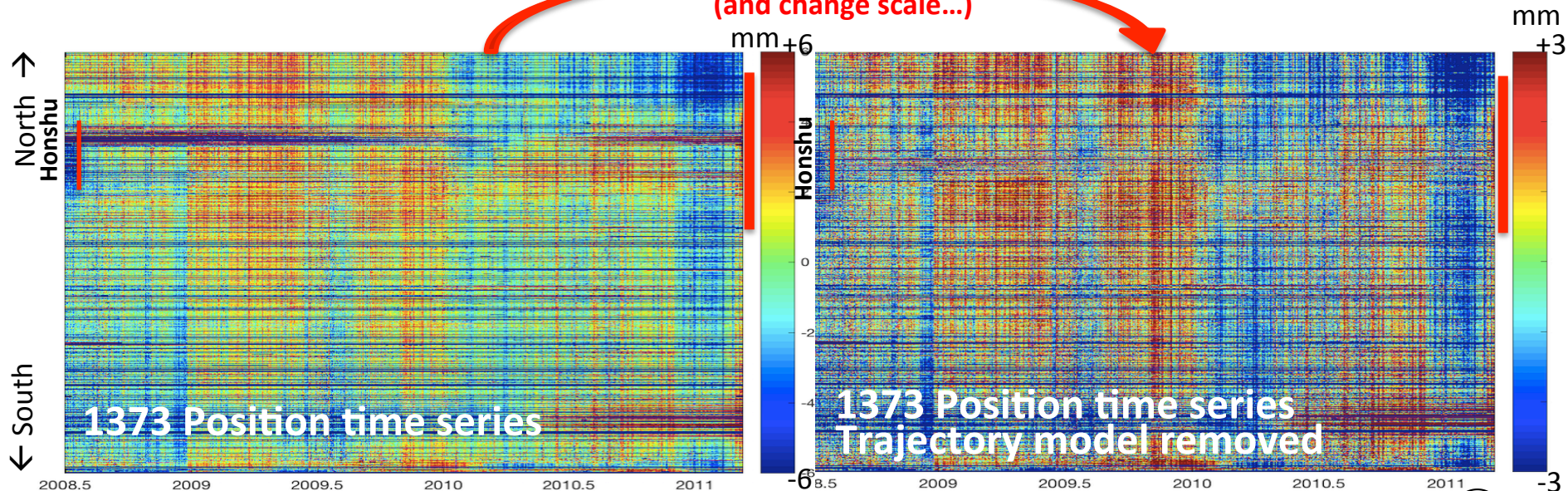


GEO-Net network analysis (3 years before Tohoku)

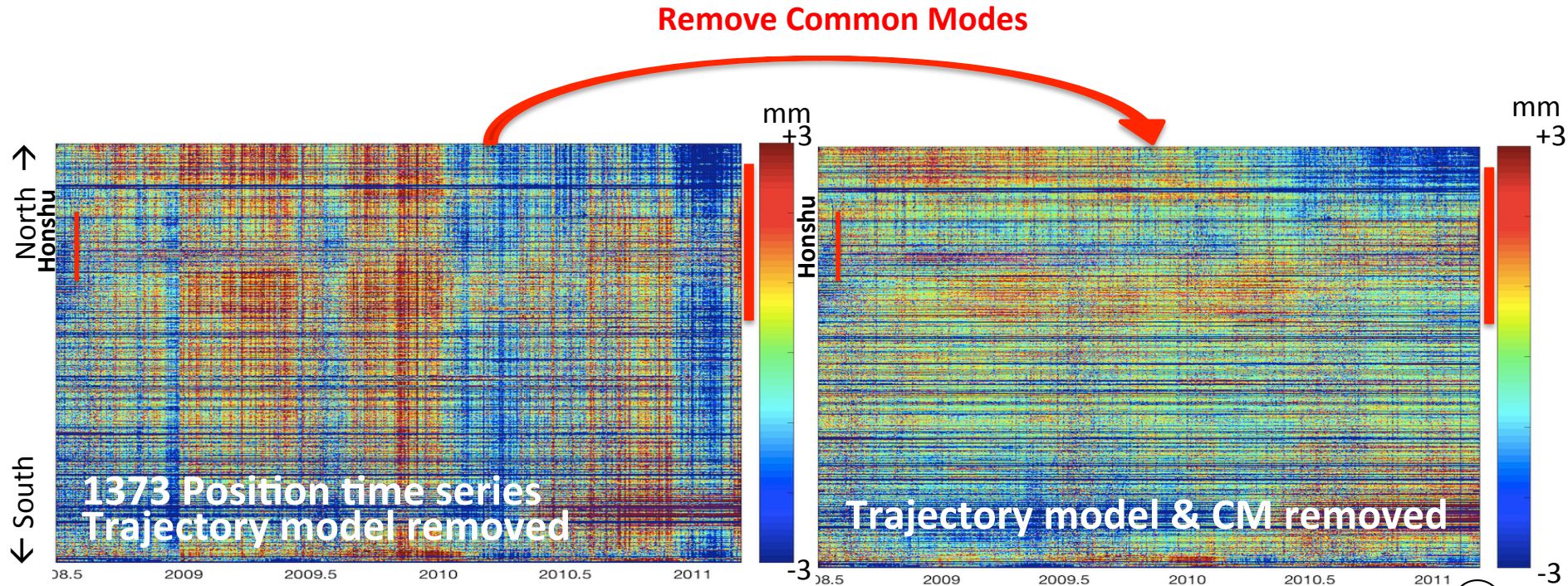
$$x(t) = x_R + v(t - t_R) + \sum_{k=1}^2 [s_k \sin(2k\pi(t - t_R)) + c_k \cos(2k\pi(t - t_R))] + \sum_{j=1}^{n_J} b_j H(t - t_j) + \sum_{s=1}^{n_S} d_s J(t - t_s) + \sum_{i=1}^{n_i} a_i \log\left(1 + \frac{t - t_i}{T_R}\right)$$

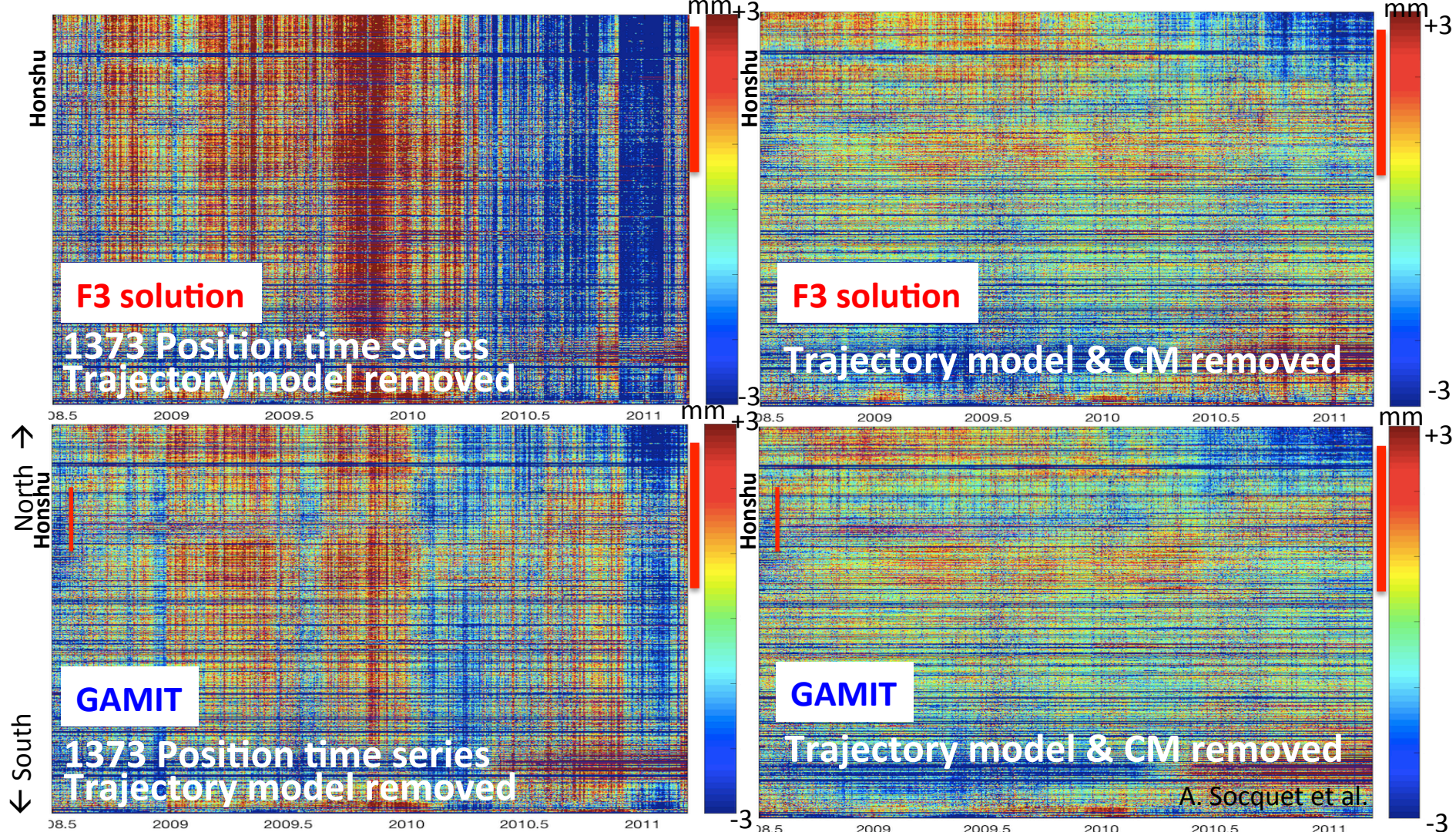
Remove Trajectory model

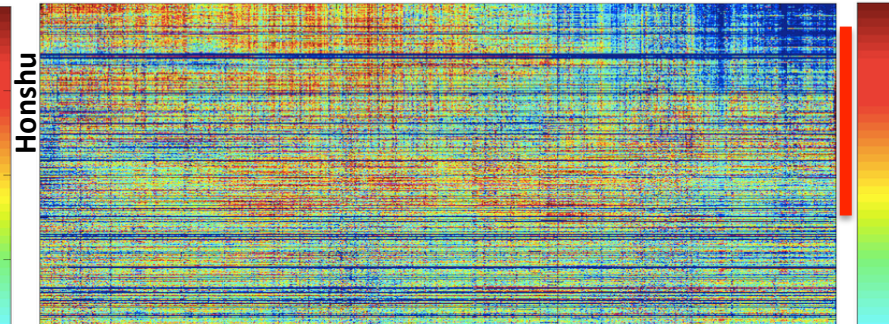
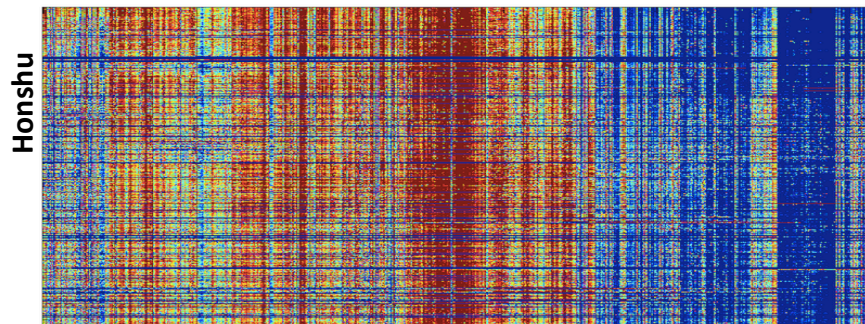
(and change scale...)



GEO-Net network analysis (3 years before Tohoku)



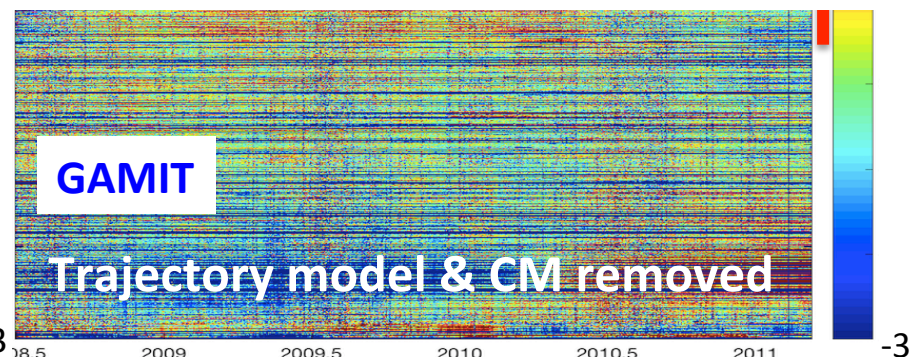
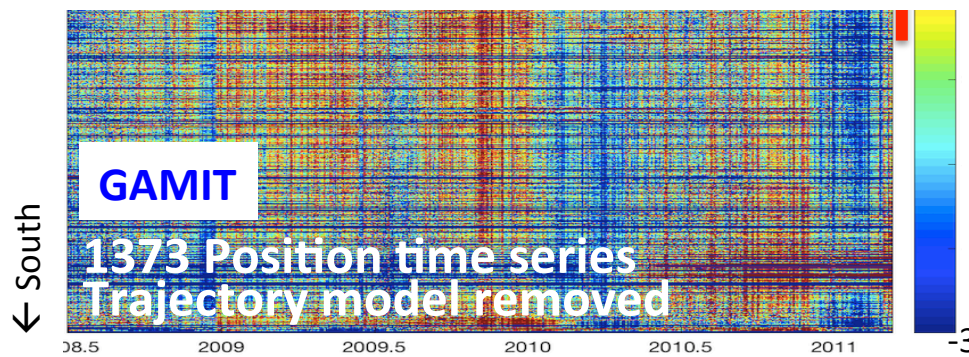


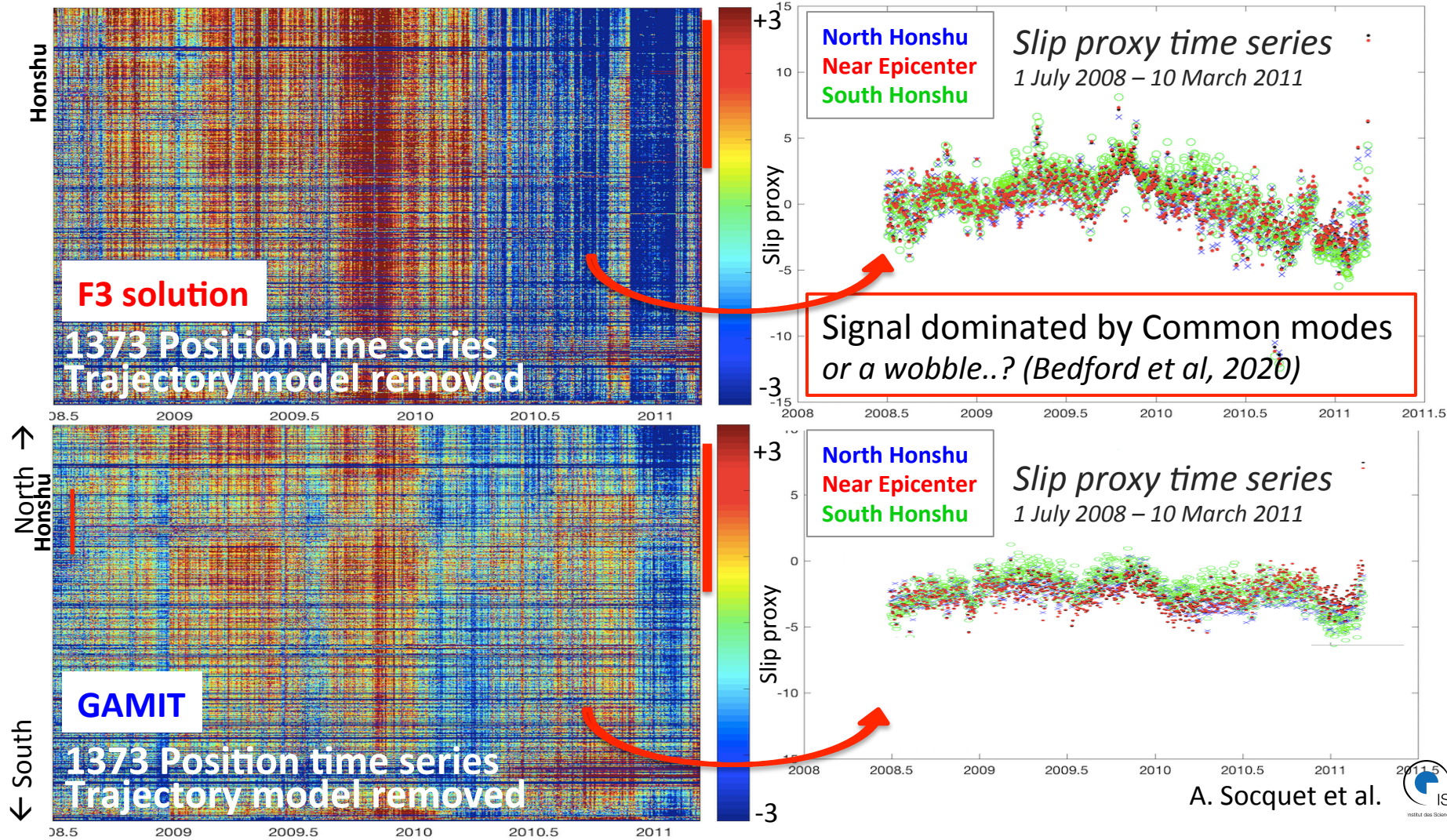


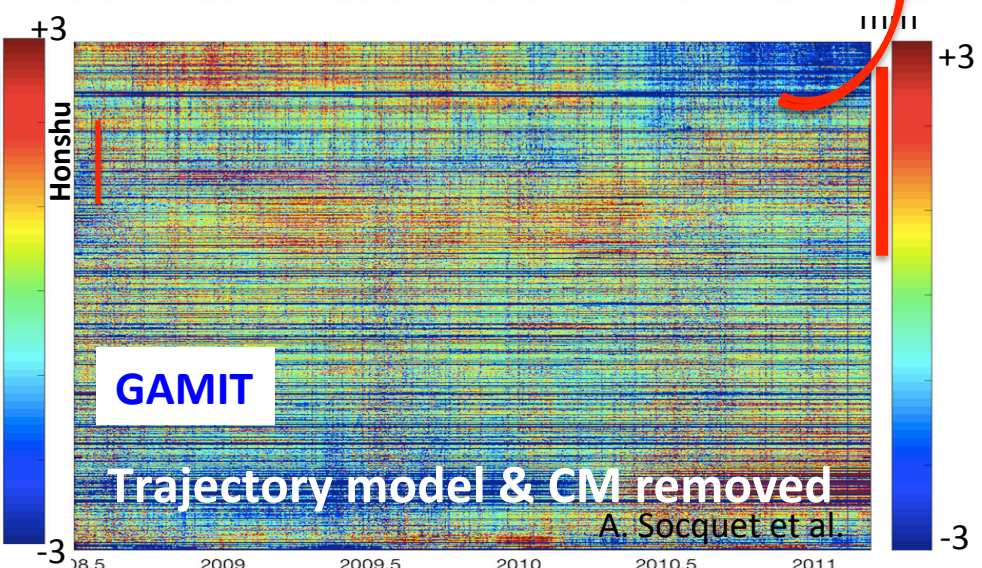
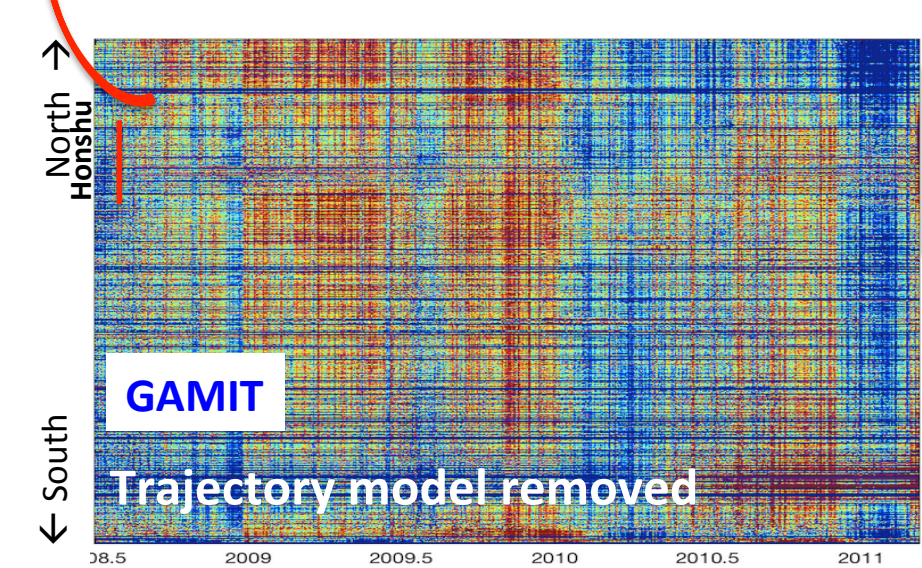
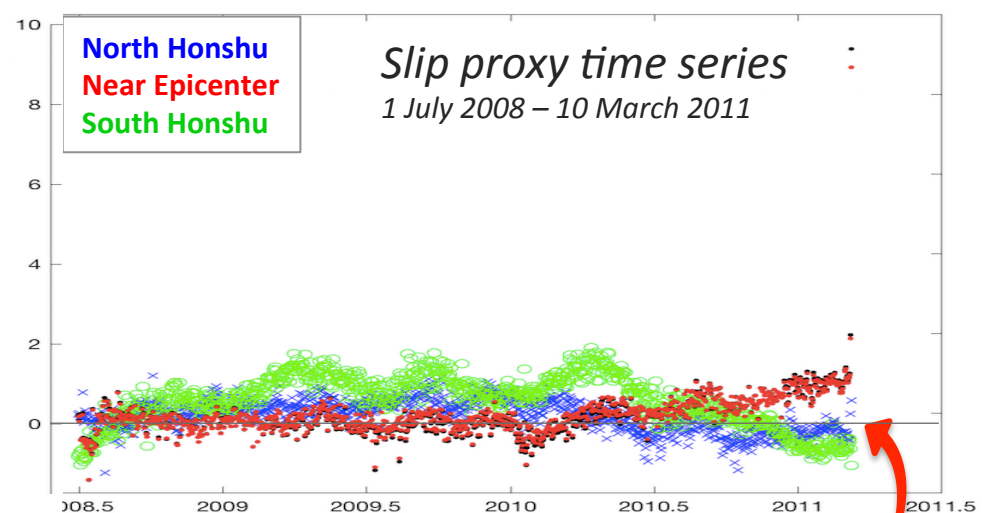
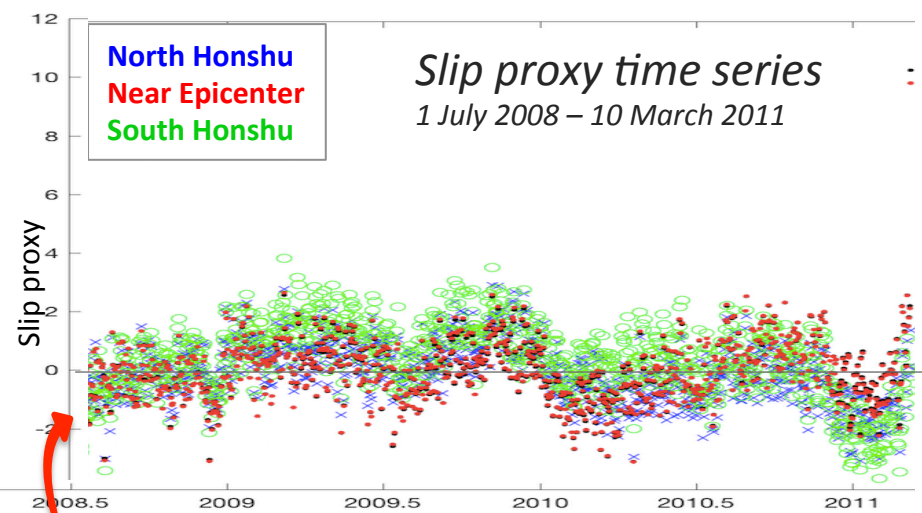
How can we see something?

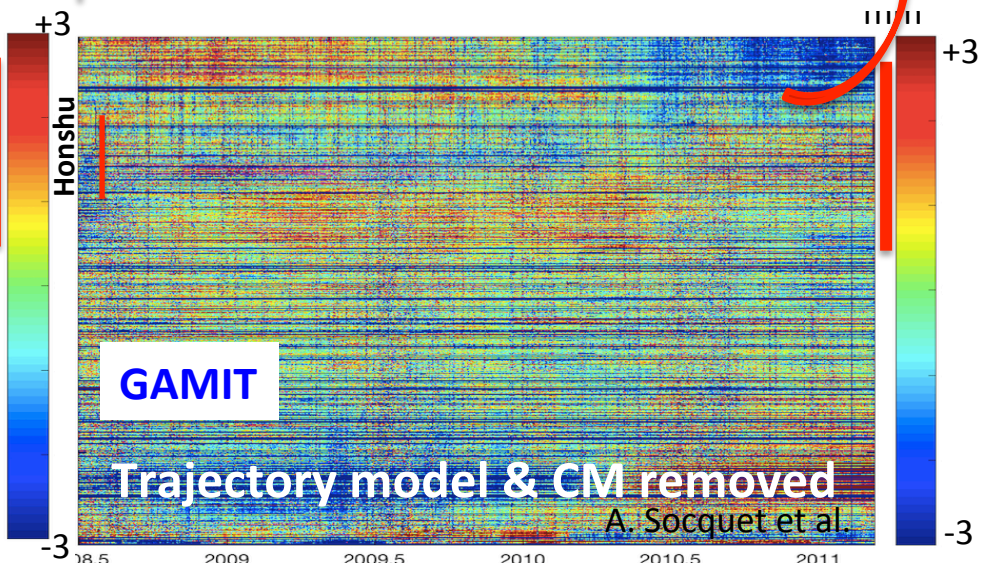
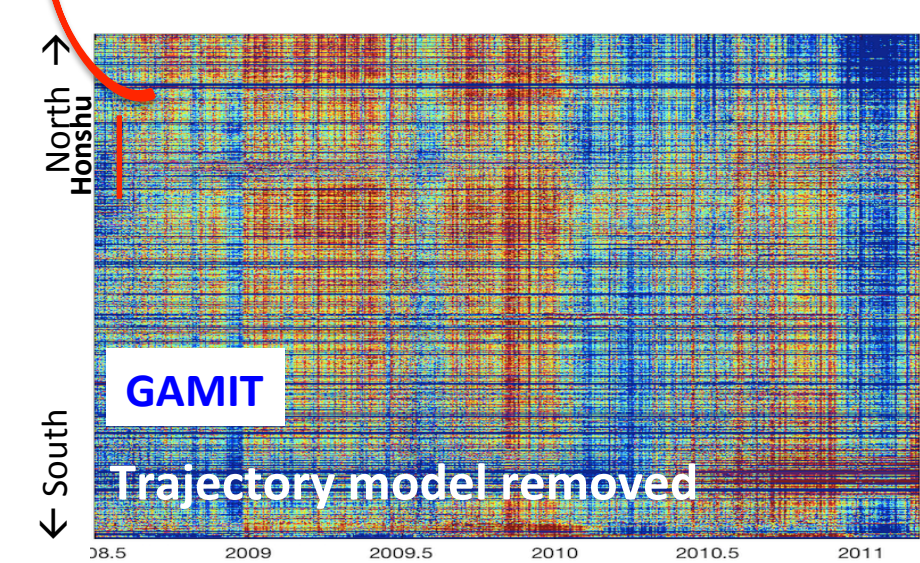
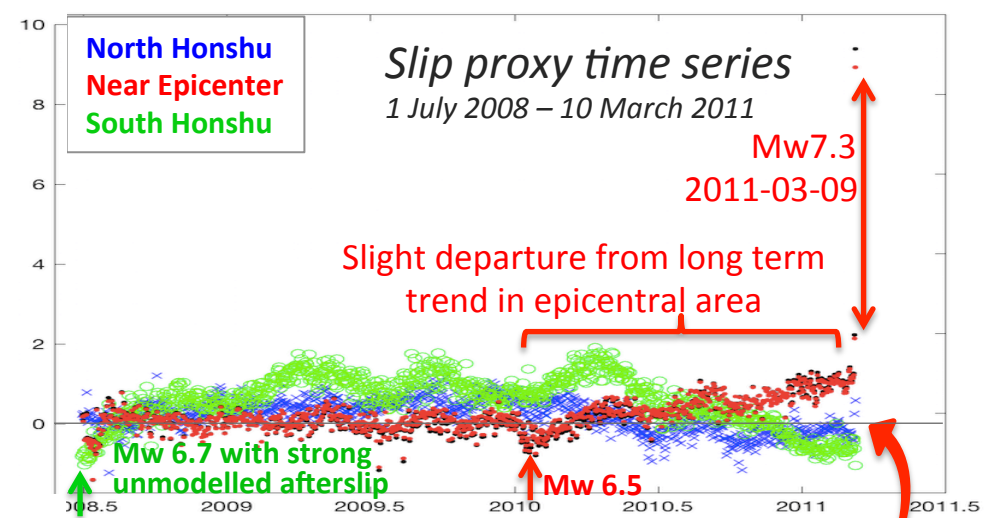
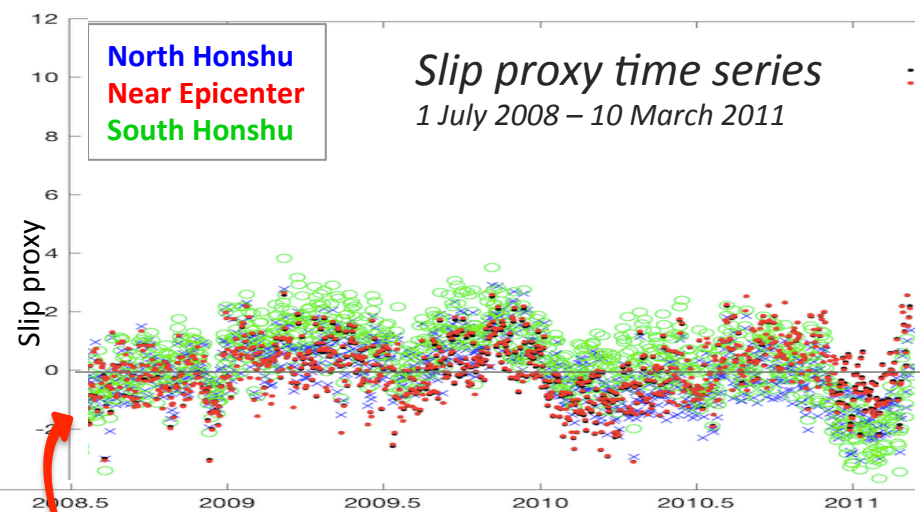
→ *stacking & array filtering*

➔ *Computation of slip proxy on the megathrust interface*









1- Is the 10-year slow deformation before Tohoku also observed in independent GPS solution and analysis?

Yes – accelerated slow slip during the decade preceding Tohoku earthquake is confirmed :

- stronger coupling increase north of Honshu
- accelerated slip offshore Boso
- rougher slip distribution

Accelerated slip also corresponds to a long-term accelerated seismicity rate

2- Is the short-term pre-seismic transient visible in GPS time series?

Maybe...

- signal of the Mw7.3 2011-03-09 strongly pops up
- in 2010, slight departure from long term trend in epicentral area coeval with Mw 6.5

Wobble versus common modes ? Question is still open (at least for me)