

Study of the early postseismic phase of Tohoku-Oki earthquake (2011) with kinematics solutions

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Summary:

Figure 1a. Horizontal Displacement obtained with kinematics solutions - 325 stations Japan (GEONET)

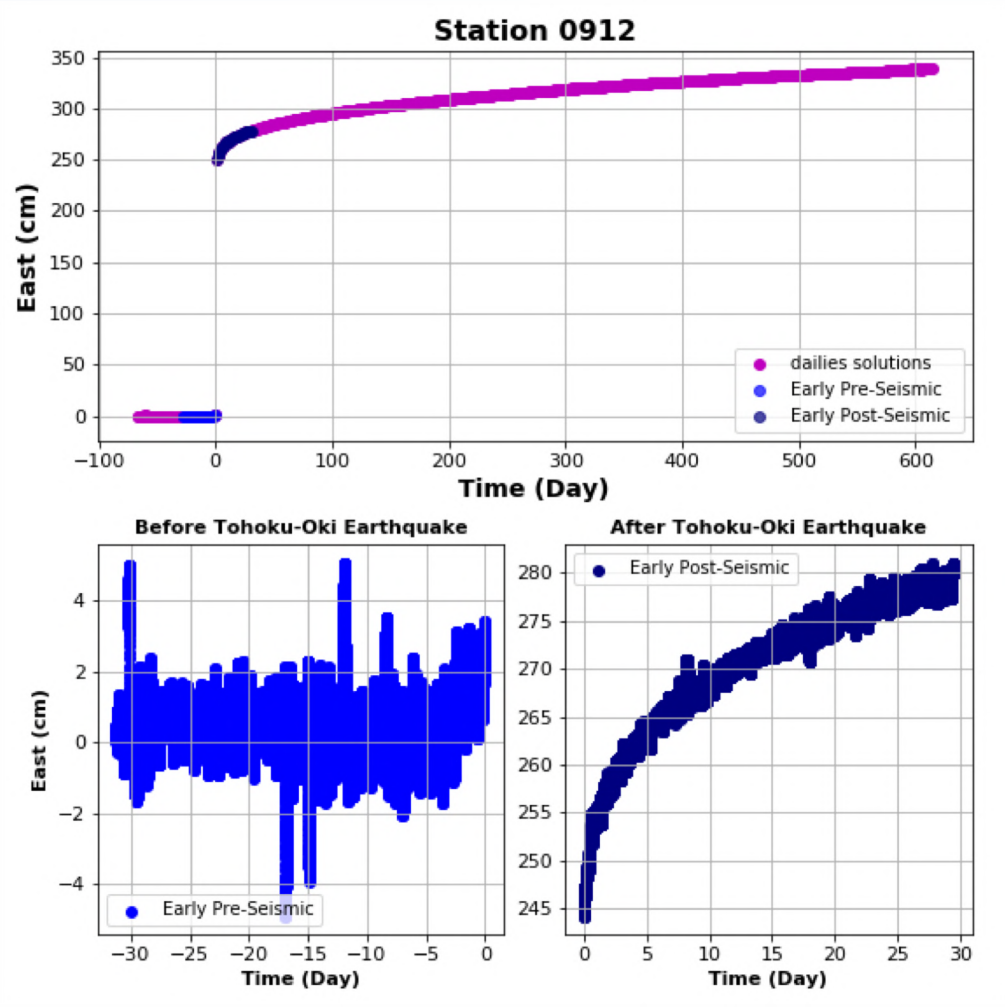
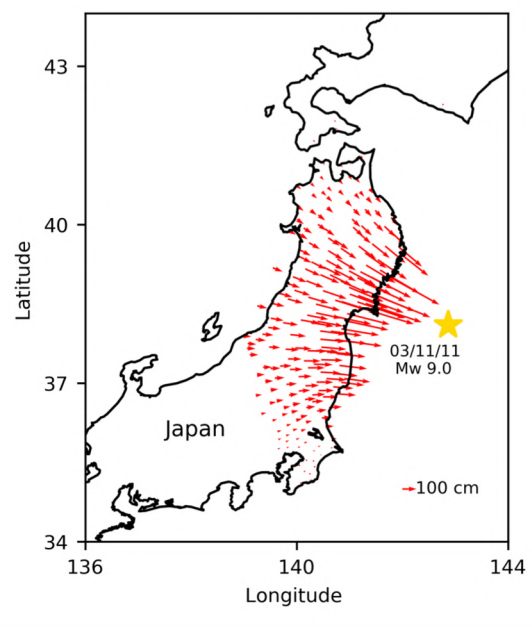
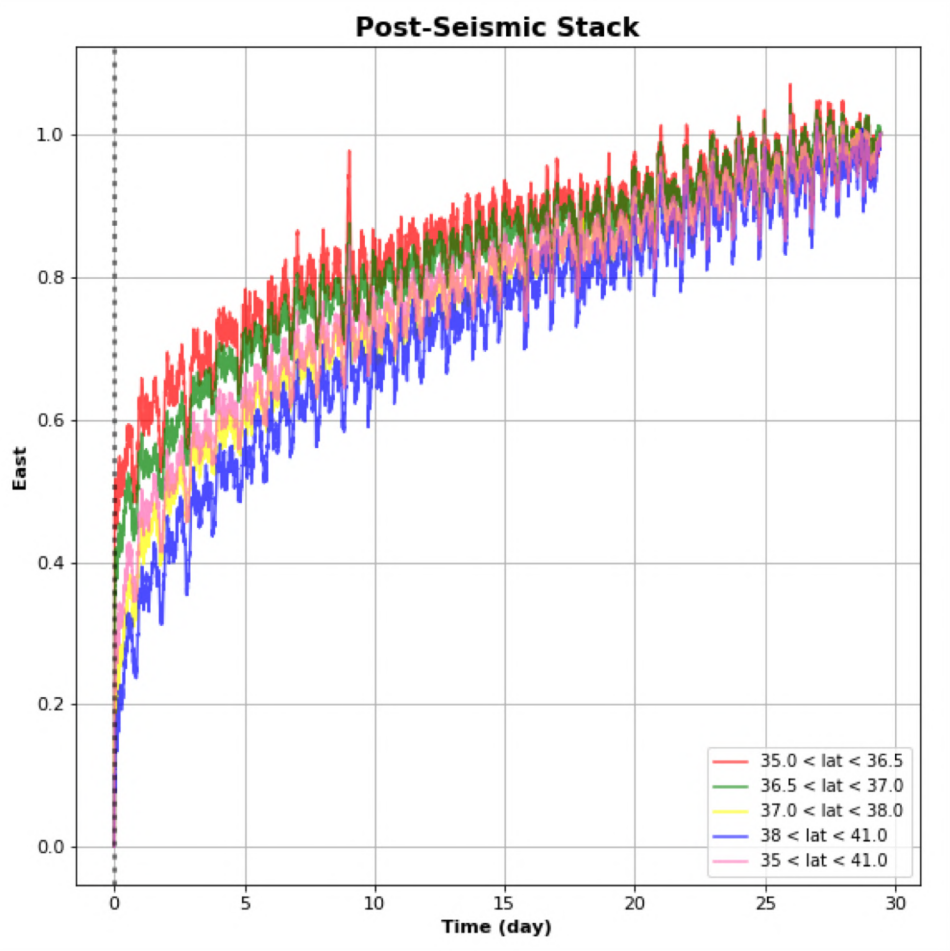


Figure 1b. Improving temporal resolution of dailies solutions to kinematics solutions – Station 0912 Japan (GEONET)

Figure 1c. Evolution of early Post-Seismic Phase of Tohoku-Oki – Stations Stack by Location (GEONET)



Context: Japanese Subduction

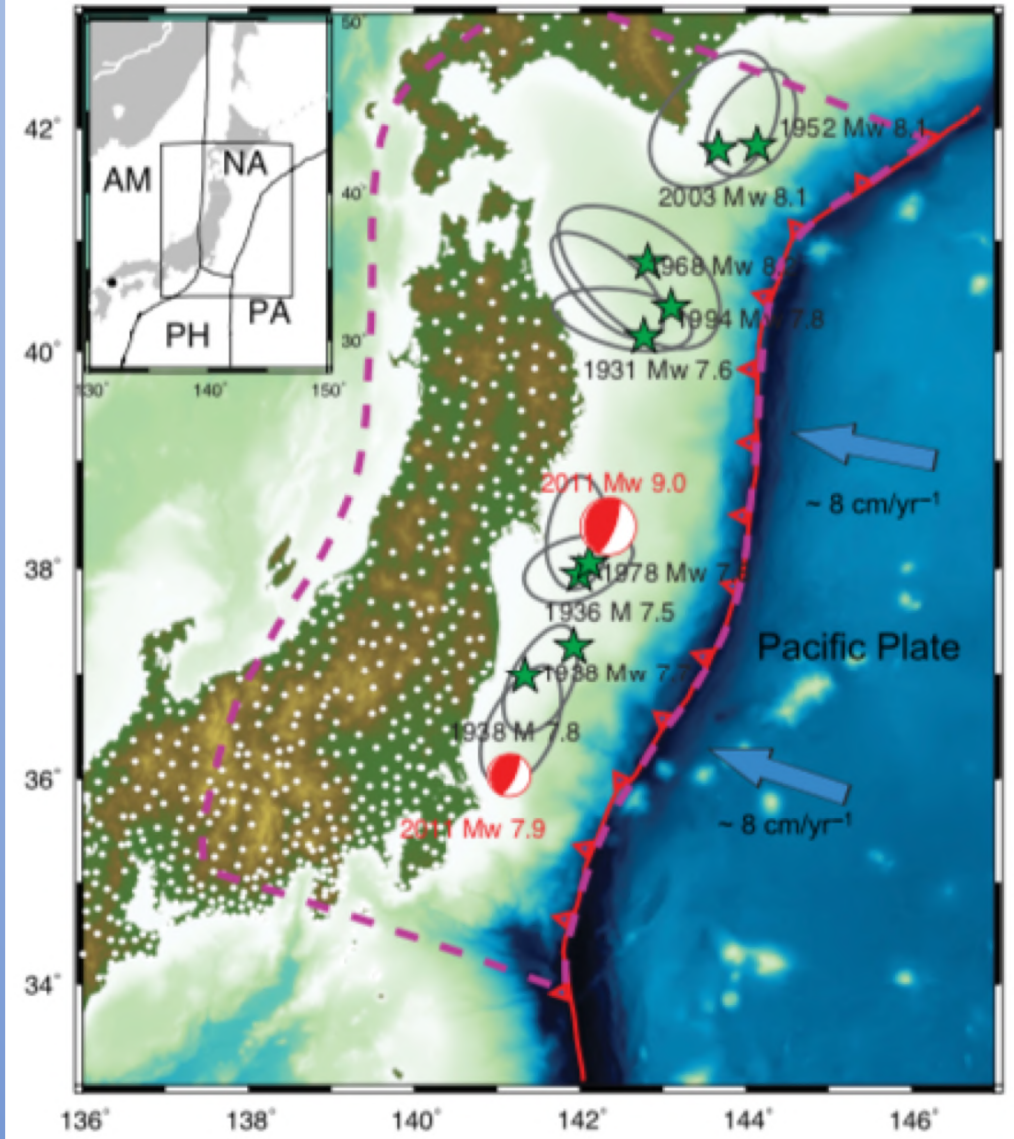
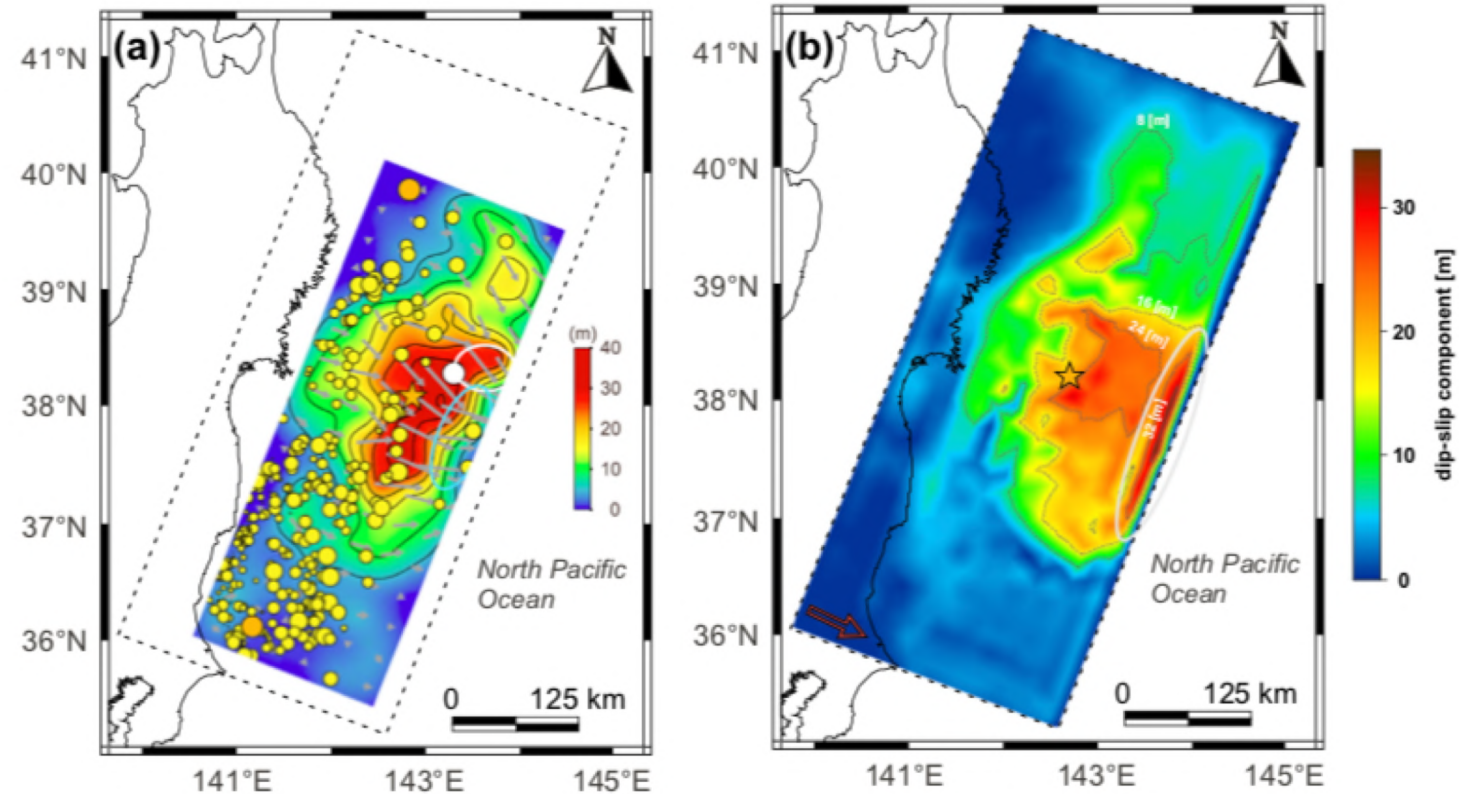


Figure 1. Tectonic settings on Japan [Diao et al. 2013]. Green stars represent epicenters. White dots represents GPS stations from GEONET network

Figure 2. Co-Seismic slip distribution from a) [Yokota et al. 2011] b) [Pulvirentin et al. 2014]



- ➔ There are multiple co-seismic models that have been obtained for the mainshock.
- ➔ How is the **seismic cycle** in these very active zone?

Geodesy: Seismic Cycle from GPS Observations

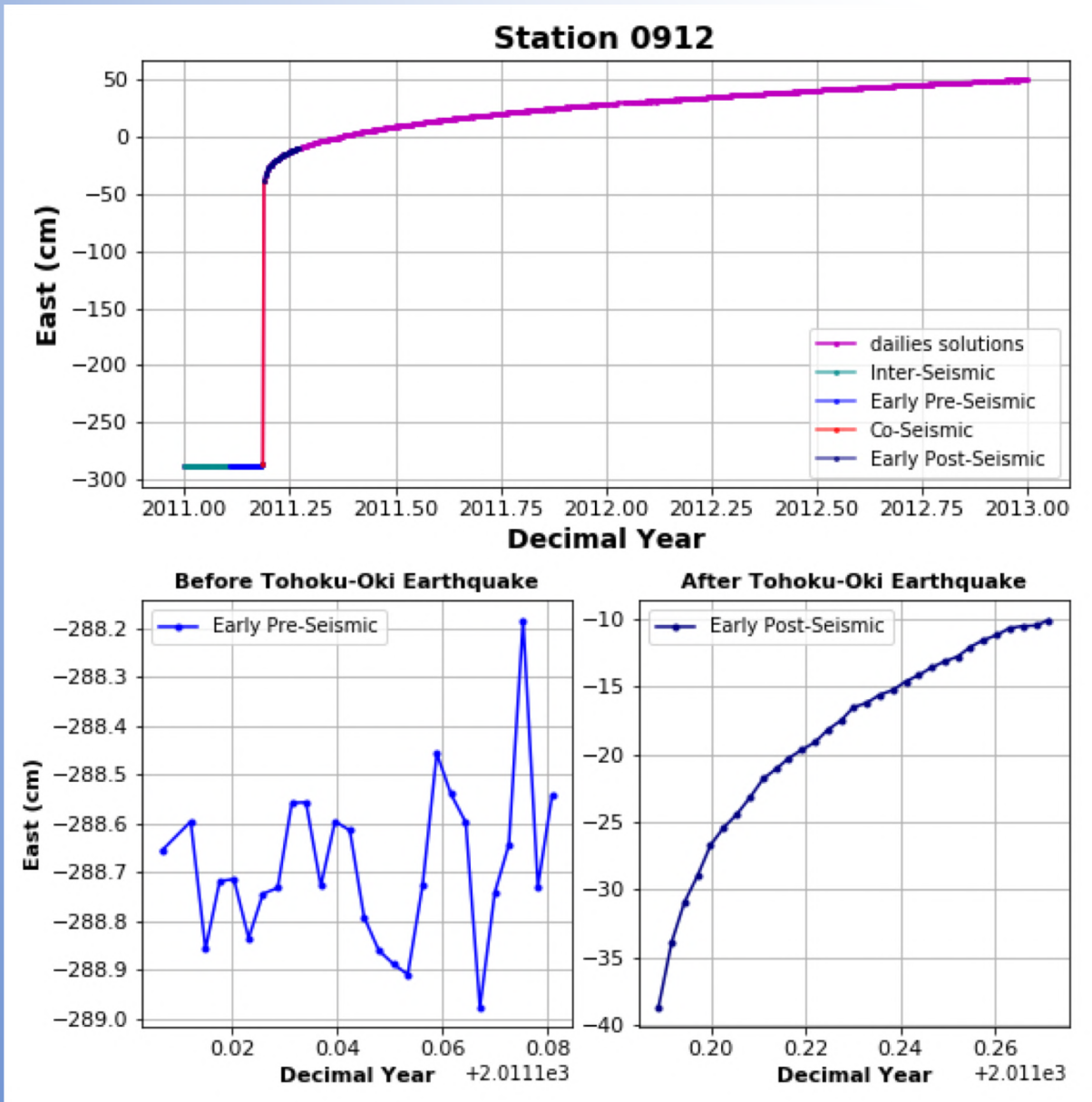


Figure 3. Time Series on East Component – Eastern Motion on Station 0912 (GEONET)

Cyclic behavior: [Reid H. F., 1906]

- ➔ How these phases **evolve** in **time** and **space**?
- ➔ What are interactions **between** seismic and aseismic slip?

Our approach:

- ➔ Look at the seismic cycle using position time series with high temporal resolution (30s sampling). We do that by processing the data with **kinematic precise point positioning**
- ➔ To improve the temporal resolution of Time Series on GEONET network

Our Software:

- ➔ GipsyX/Oasis from JPL
- ➔ « PPP » Absolute Positioning with centimeter accuracy

Processing with GipsyX: Strategy applied from [Twardzik et al 2019]

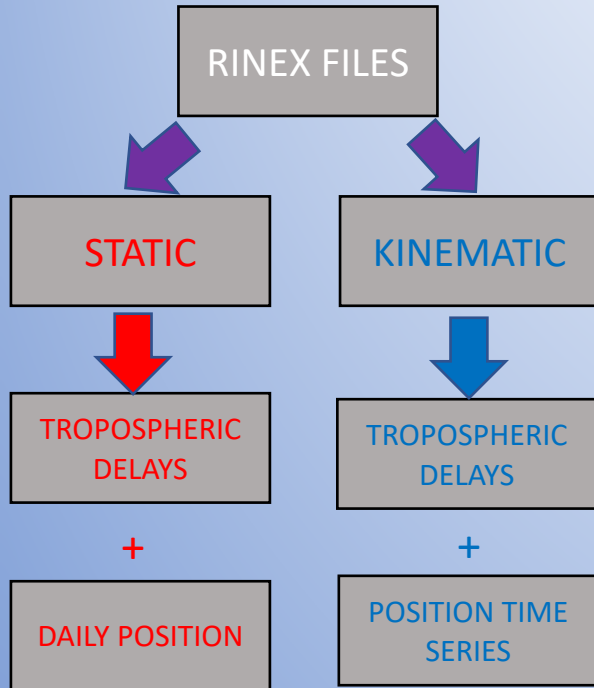
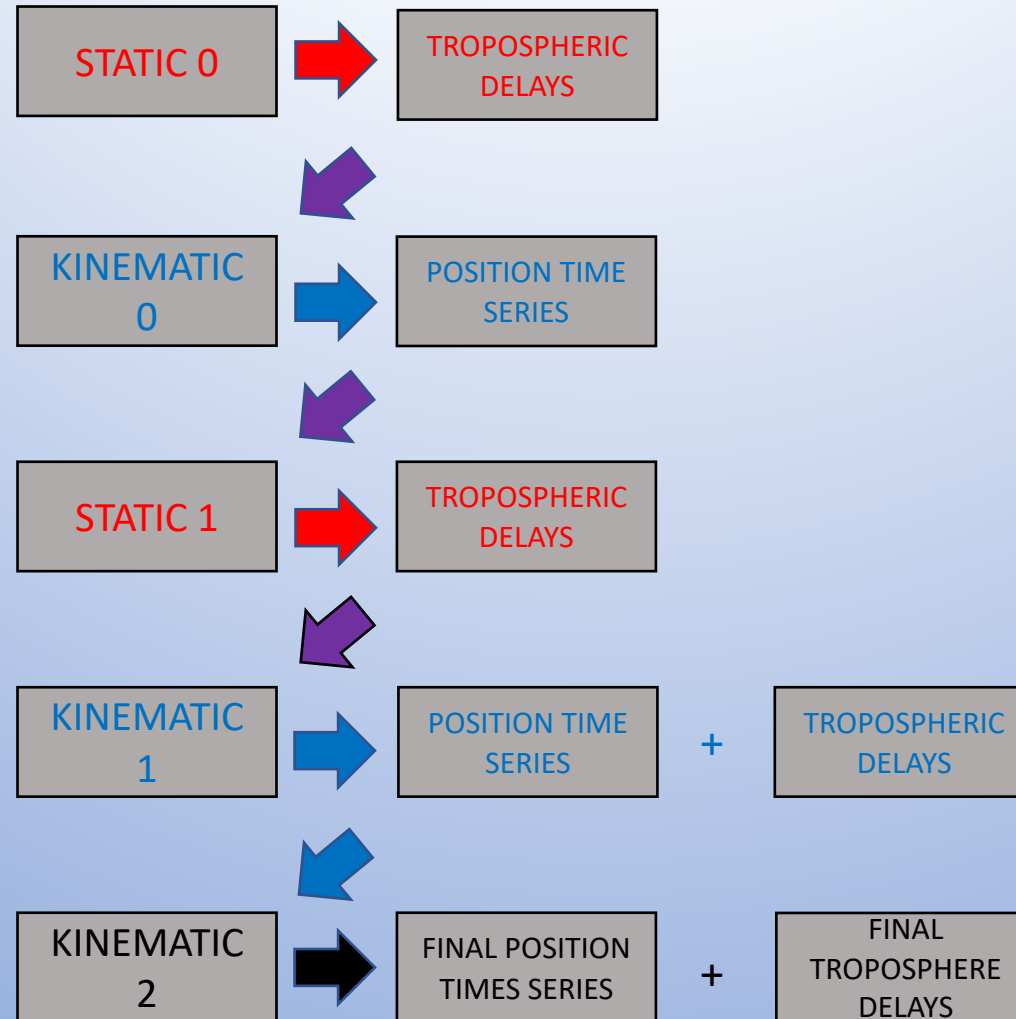


Figure 4. Scheme of strategy applied to process data



- Ocean Loading effect is correct with FES2014b model
- Ionospheric correction first order and second order with IRI model
- Tropospheric correction with VMF1 Mapping Function

Processing with GipsyX: Kalman Filter

→ Kalman Filter Main Features:

- Estimation of the positions from GPS observations as recursive estimator
- Controlled by randomwalk value.
- There is an estimation on each epoch:

→ **Randomwalk value** is given by the litterature from [Choi Dissertation] [Selle and Desai] [Twardzik et al 2019]

→ We still did some sensibility test to understand and observe the evolution of times series in function of parameter value.

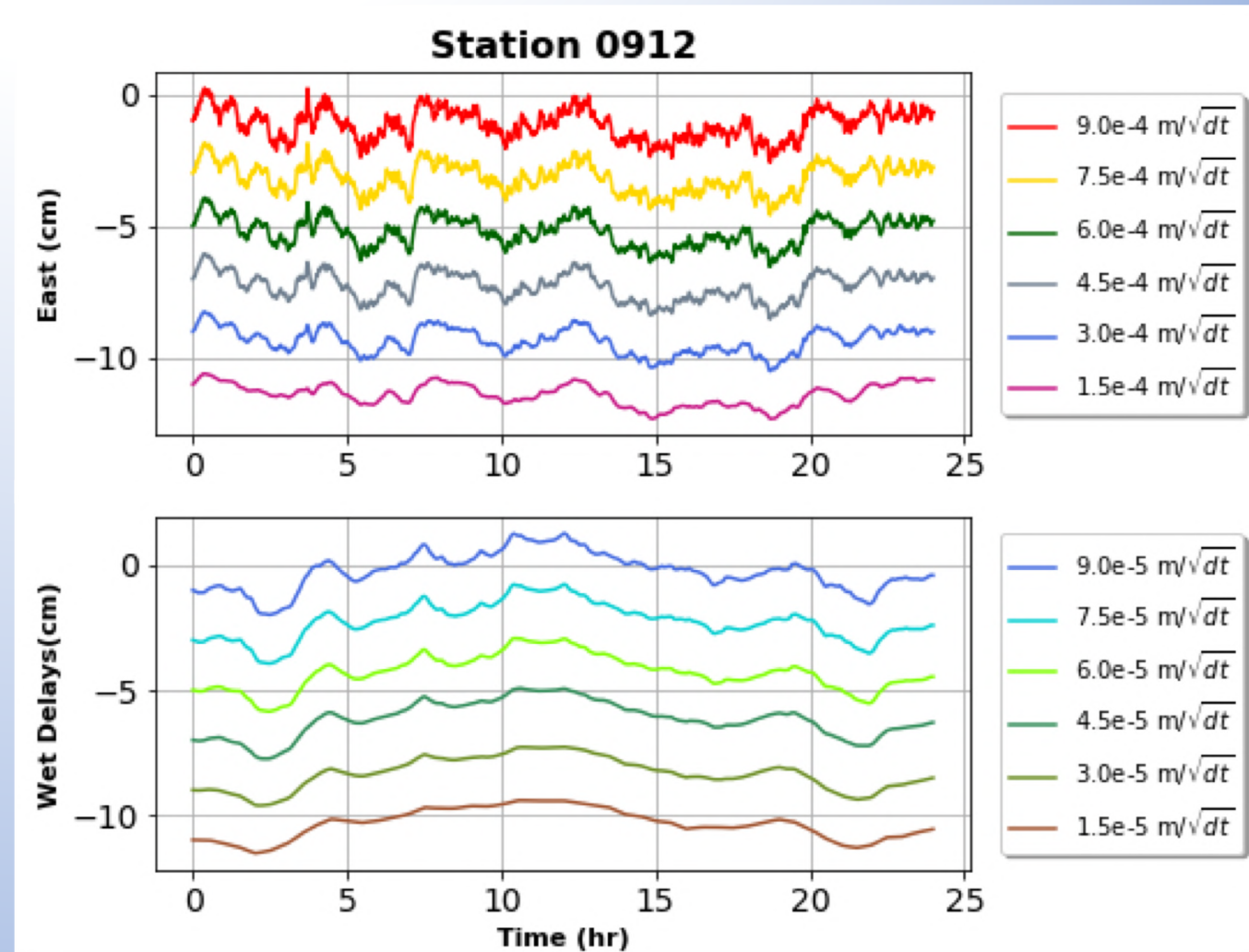


Figure 5. Time Series on Eastern Motion and Wet delays – on Station 0912 (GEONET)

→ The choosen value correspond to royal blue curves:

Position $3.0 \times 10^{-4} \text{ m}/\sqrt{\text{dt}}$

Wet Delays $9.0 \times 10^{-5} \text{ m}/\sqrt{\text{dt}}$

Post-Processing: Multipath Effect and Sidereal Filter

➔ The signal recorded by GPS station is not only the direct EM waves but also reflected waves: **Multipath**

➔ [Twardzik et al 2019] shown a way build a sidereal filter. with displacements without tectonic signal.

Steps:

1. Cross-Correlation between two different days.
2. Stack both days with the time-shift found
3. Cross-Correlation between the stack and another day.
4. Update the stack.
- N. Update the stack untill n days..

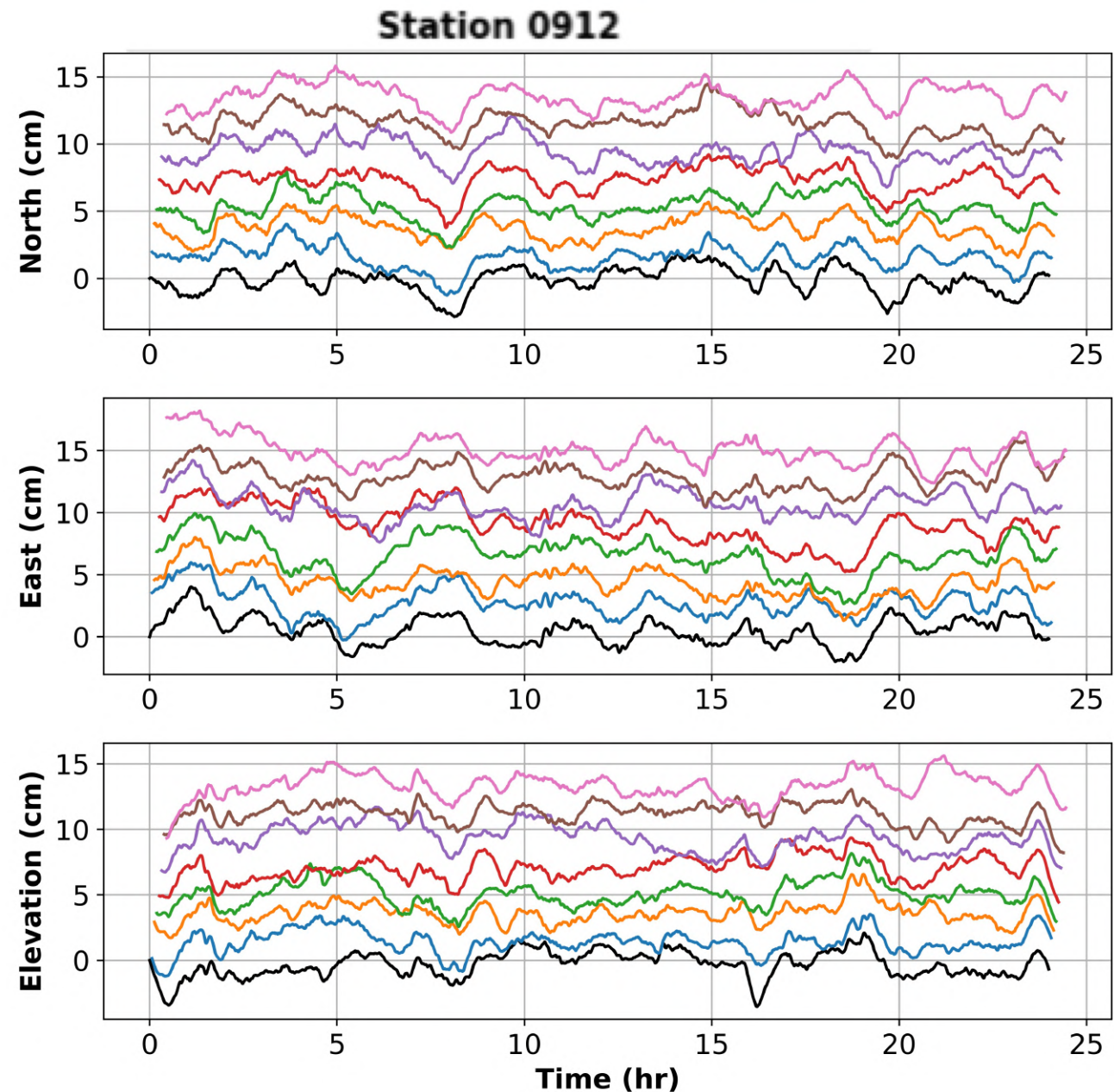


Figure 6.
Time
Sidereal
Evidence -
Series of
successive
days on
three
component
– on
Station
0912
(GEONET)

Post-Processing: Sidereal Effect details

➔ To determine the number of days to build the **Sidereal Filter**, we compute the rms of the serie after the correction.

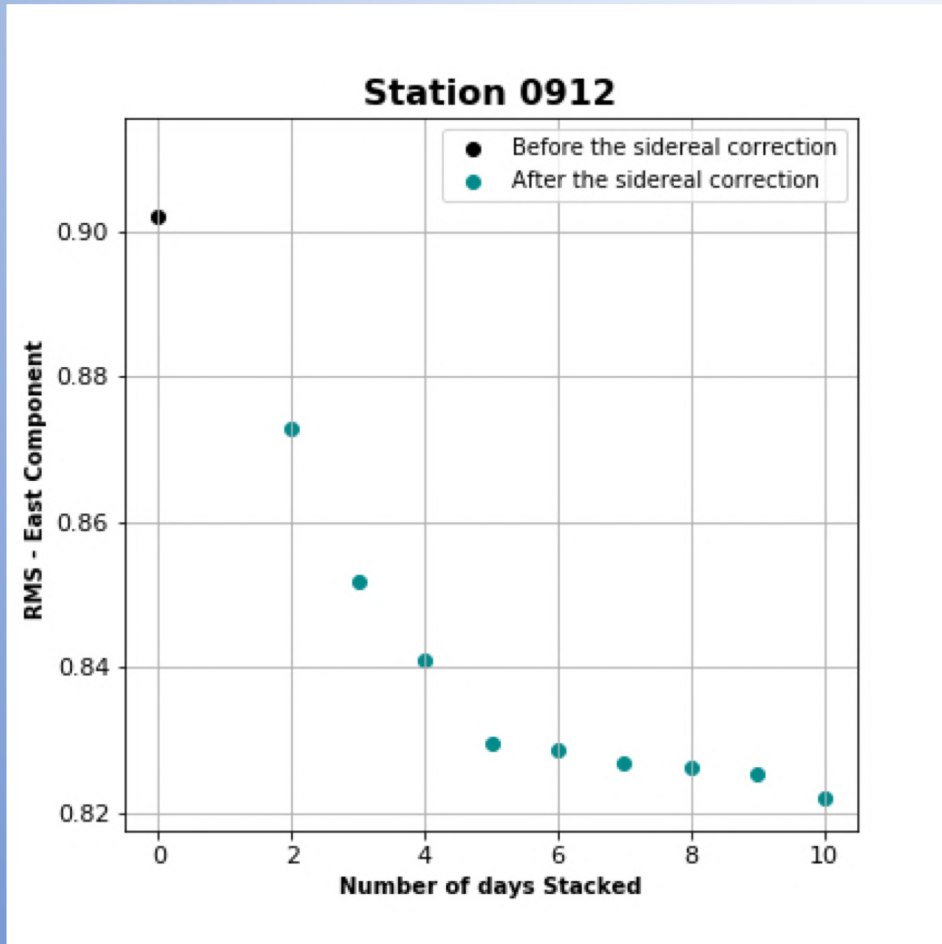


Figure 7a. Evolution of the RMS before and after the Sidereal Filter [Twardzik et al 2019] – on Station 0912 (GEONET)

➔ Here, an example of the time-shift computed by the cross-correlation for each step of the stack.

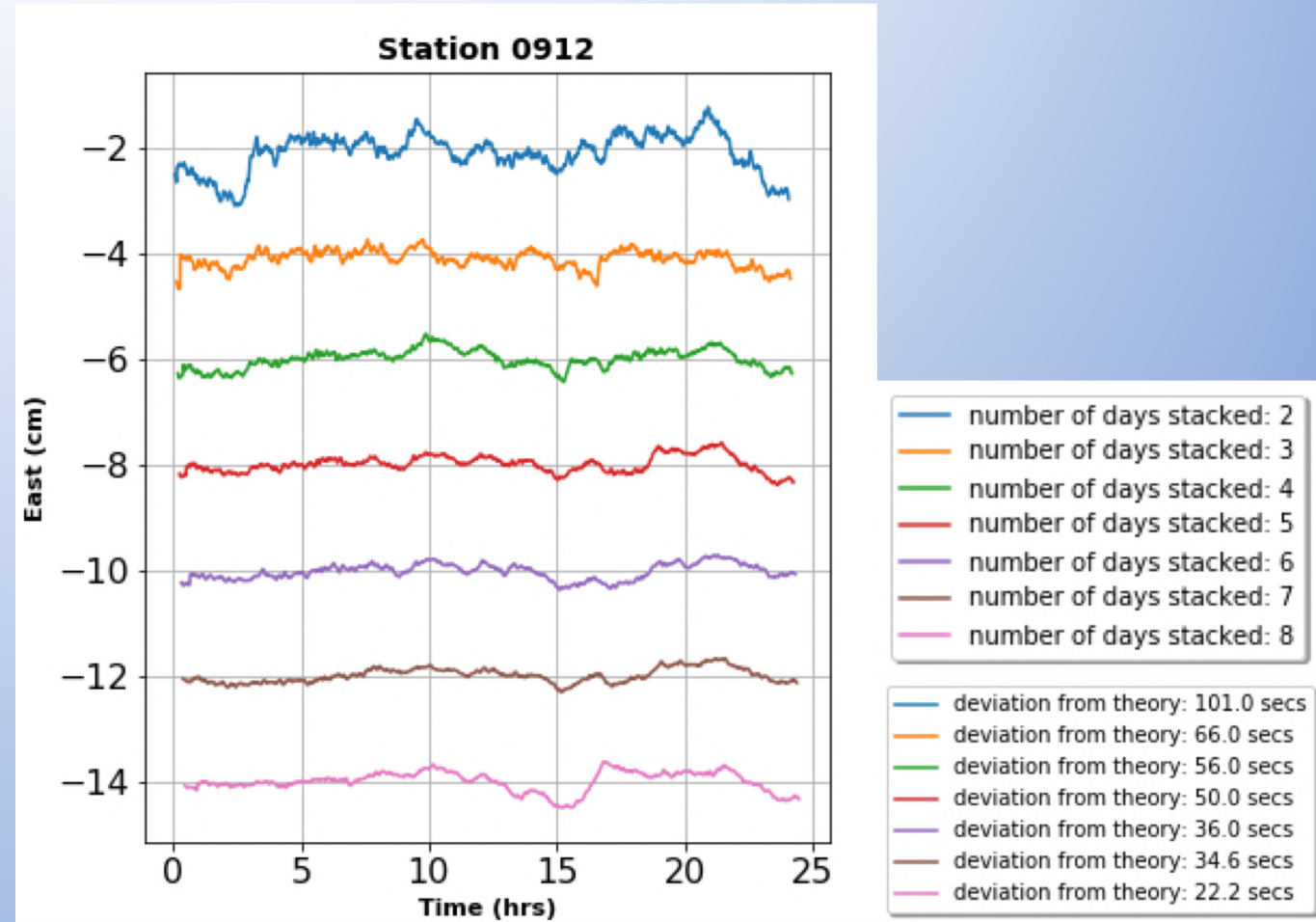
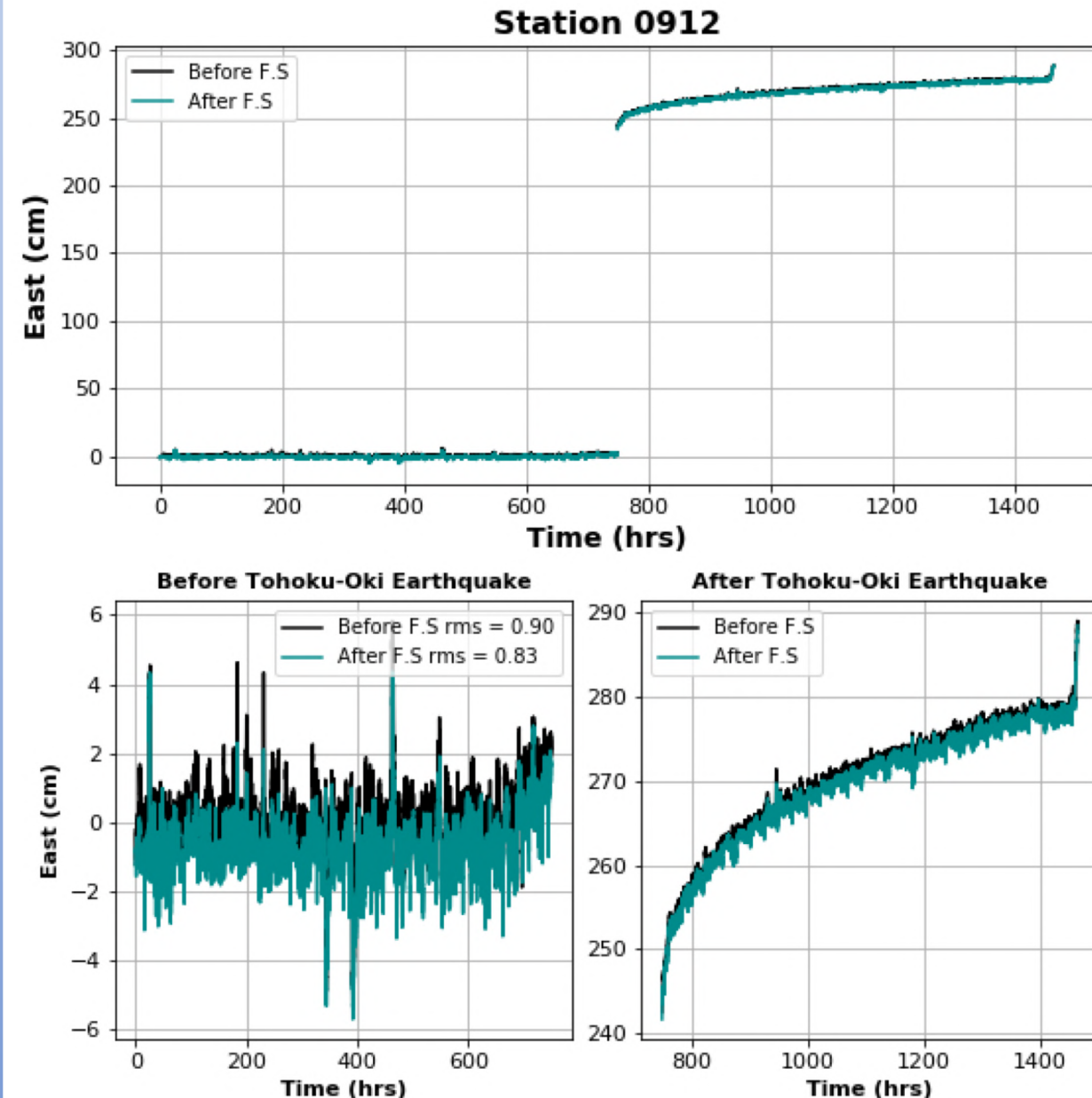


Figure 7b. Stack evolution with number of days stacked – on Station 0912 (GEONET)

Post-Processing: Sidereal Filter Correction on Complete Time Series



➔ Before the earthquake, we compare the rms before and after the Sidereal Filter Correction

Figure 8. Time Serie on East Component before and after F.S – Eastern Motion on Station 0912 (GEONET)

Post-Processing: Common Modes Correction

→ Common Modes: mainly miss-modelation of satellites orbits, evolving in space and time

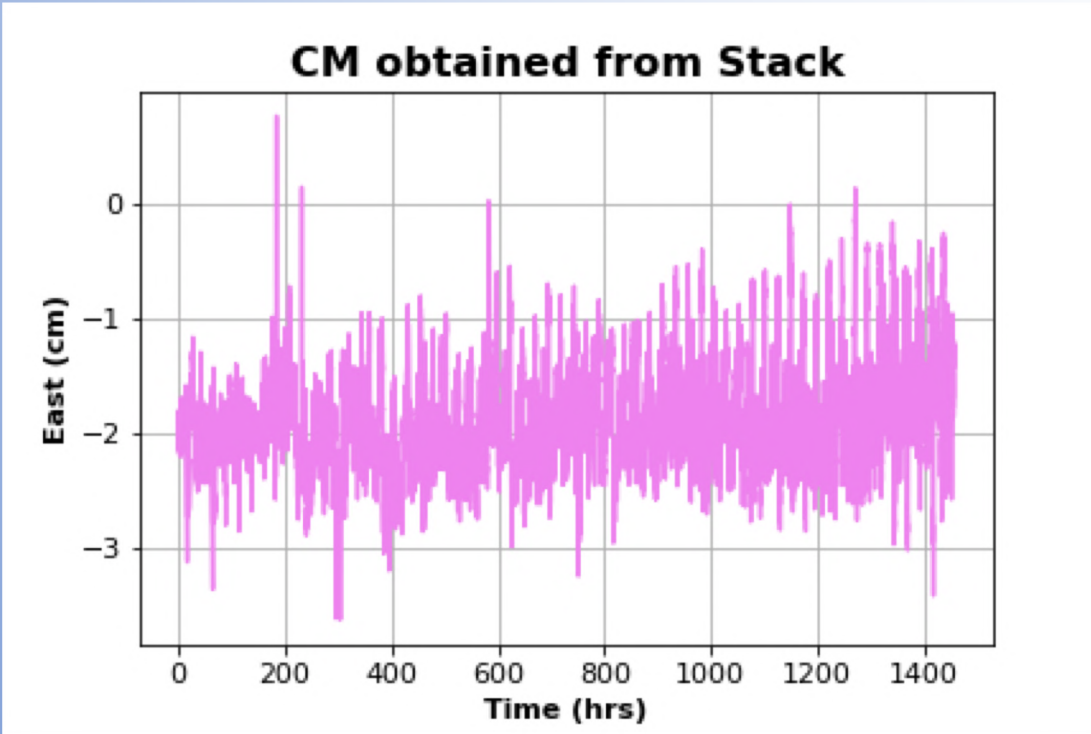


Figure 9a. Stack on East Component of stations on the Nord part of Japan (GEONET)

→ To correct this effect, the idea is to **stack non-tectonic signal** on stations far from Tohoku-Oki Earthquake influence!

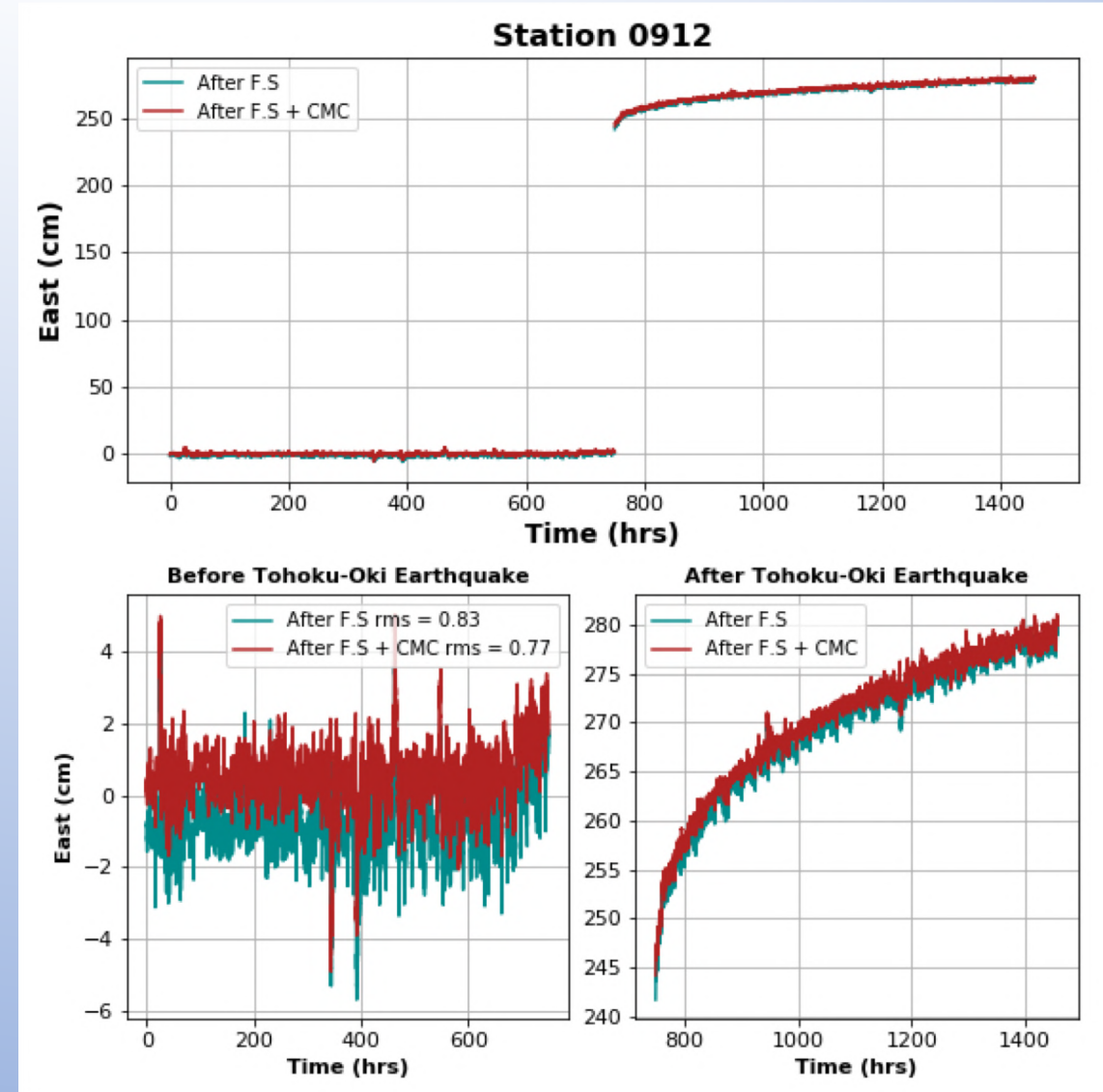


Figure 9b. Time Serie on East Component before and after F.S + CMC – Eastern Motion on Station 0912 (GEONET)

Post-Processing: Ibaraki-Oki Aftershock Mw 7.9 observations

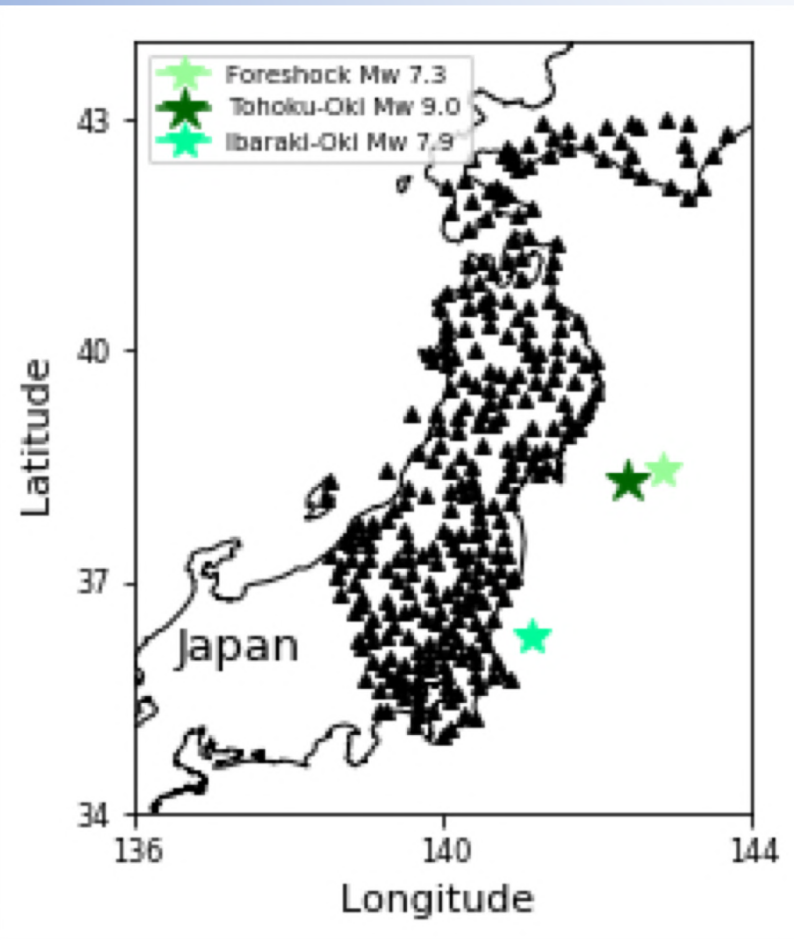


Figure 10a. Stations Processed - 290 stations on Honshu, 35 on Hokkaido (GEONET)

- Strong signal is observed ~30 minutes after the Tohoku-Oki Earthquake
- Amplitude of the co-seismic offset of Ibaraki-Oki aftershock Mw 7.9
- To isolate Post-Seismic from mainshock, we removed it from times series.

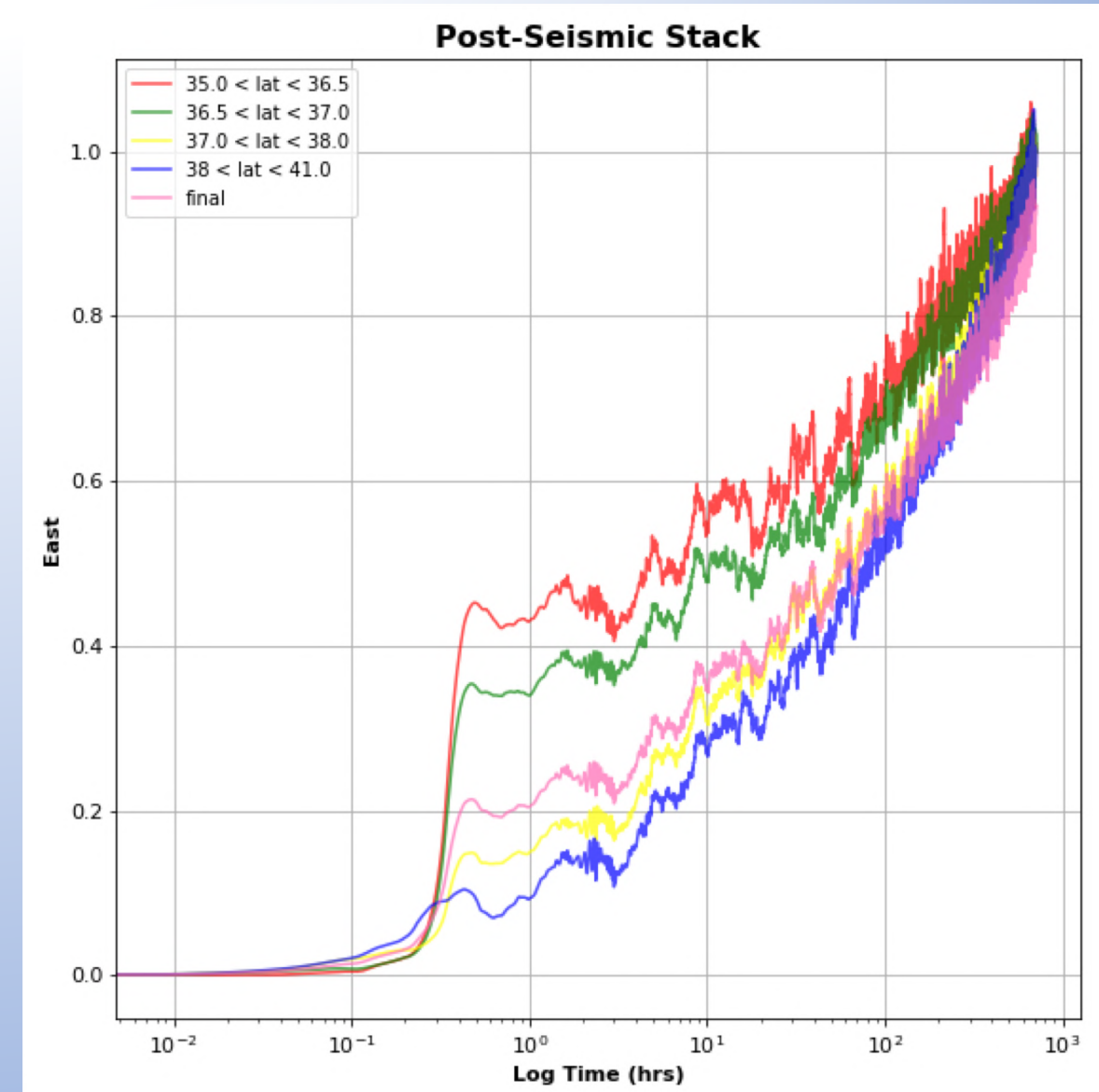


Figure 10b. Post-Seismic Stack of all stations processed—Eastern Motion 290 stations (GEONET)

Observations: Co-Seismic Displacement

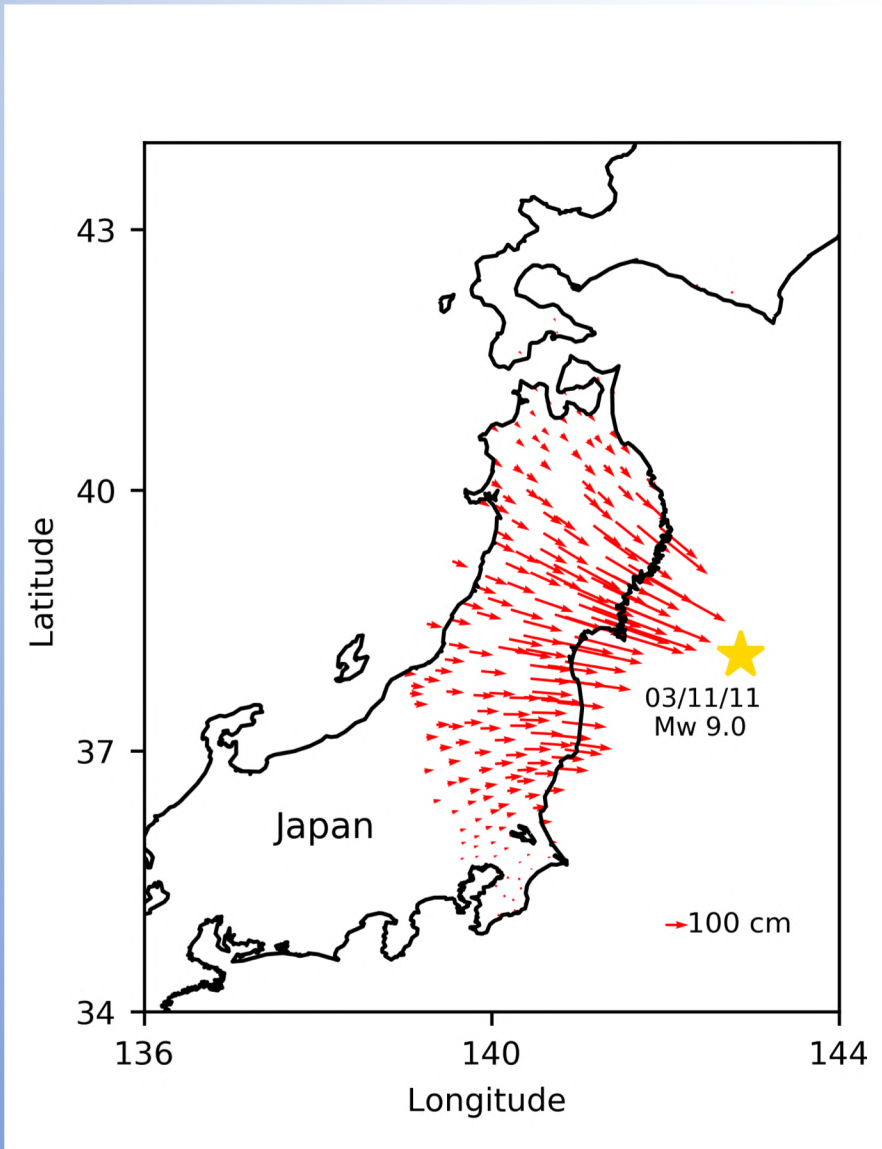


Figure 11a. Co-Seismic Horizontal Displacement of the mainshock - 325 stations Japan(GEONET)

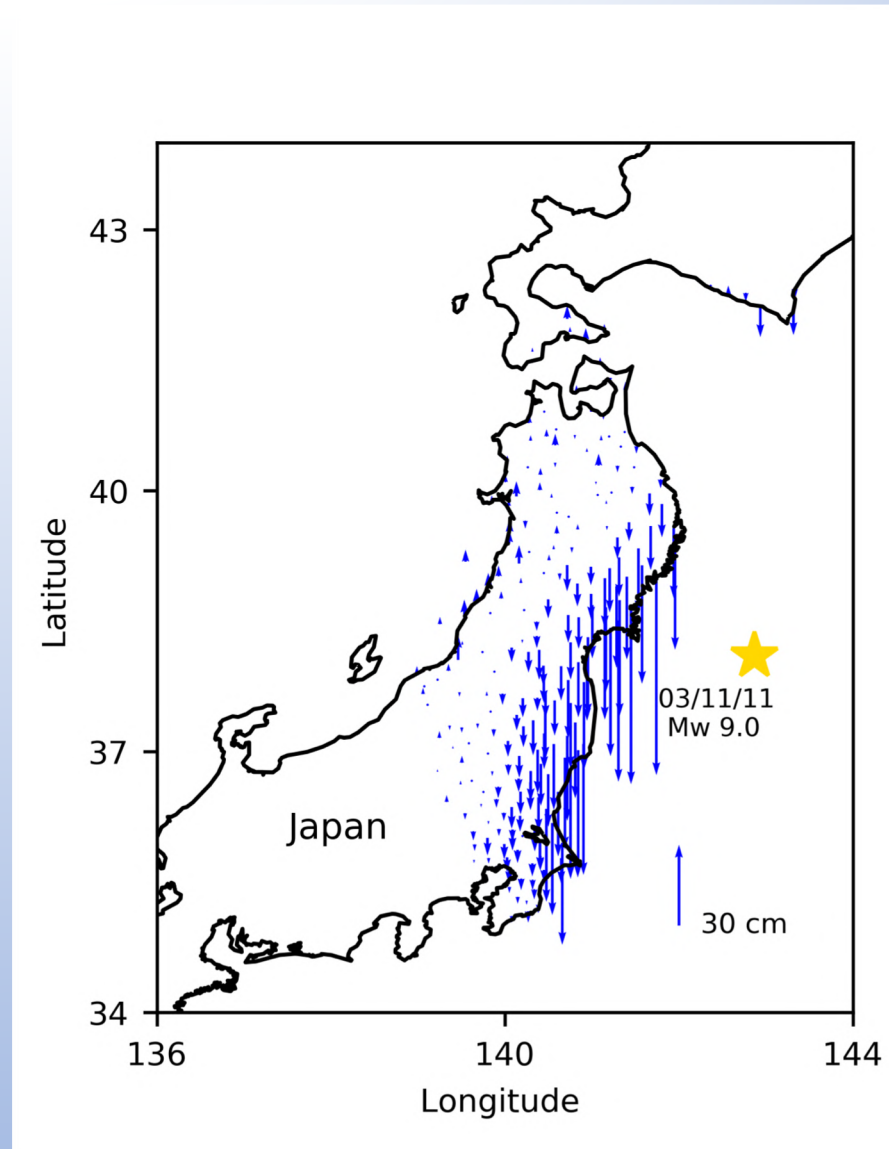


Figure 12a. Vertical Displacement - 325 stations Japan(GEONET)

Conclusions and Perspectives:

In progress:

- ➔ We are now able to retrieve the full postseismic displacement field from the first minutes to the few days after the mainshock.
- ➔ Next, we will attempt to determine which relaxation laws fit best our surface observations
 - Starting with a modified Omori's law
 - Trying some values on « p » exposant
- ➔ Using our data, we should be able to constrain the behaviour of these laws at the very early time of the post-seismic phase.
- ➔ We start to study it with stack in fonction of station location; Maybe later, we can do it with ICA, PCA approach
- ➔ Then, we will attempt to find the slip distribution of the postseismic phase.
- ➔ We also plan to study the post-seismic phase of the large foreshock (M_w 7.3) that occurs 2 days before the mainshock.
 - What is the shape of the signal before Tohoku-Oki
 - Smart-Stacking approach..

Thank you.