

Estimating surface displacement in the Hanshin area, Japan, by PS-InSAR analysis using satellite Sentinel-1 data

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2018/6/18 Northern Osaka earthquake's damage



<https://diamond.jp/articles/-/172885>

According to the Fire and Disaster Management Agency's count by August 20, 2019,

Completely destroyed houses	21
Partially destroyed houses	483
Partially damaged houses	61266

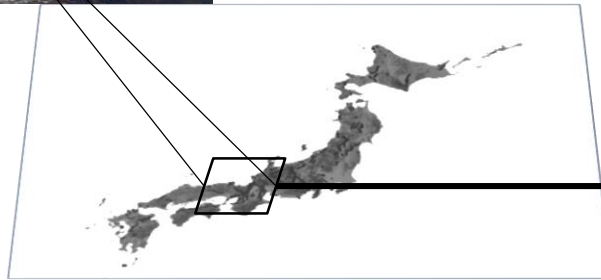


https://www.huffingtonpost.jp/2018/06/18/osaka-gas_a_23461326/

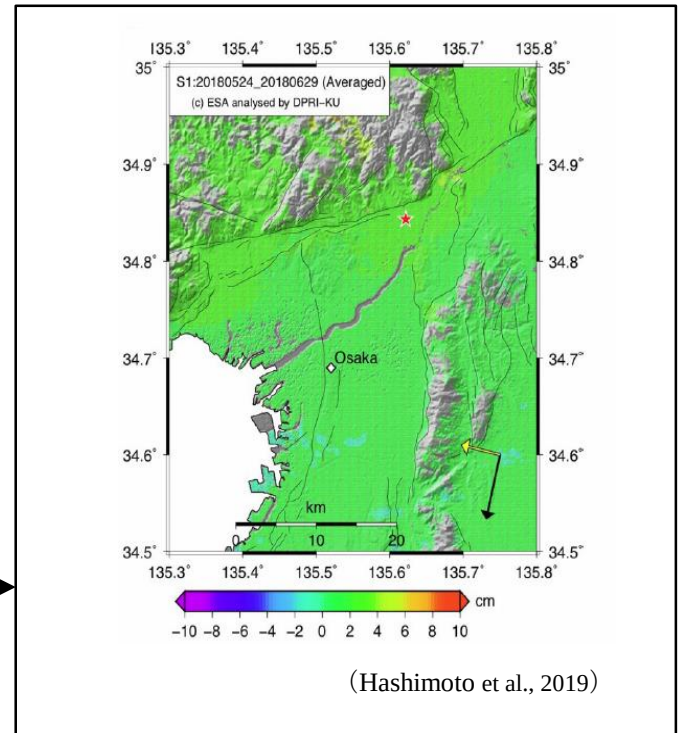
In addition, damage occurred in various industries such as electricity, gas, and railroads.

Motivation

InSAR analysis

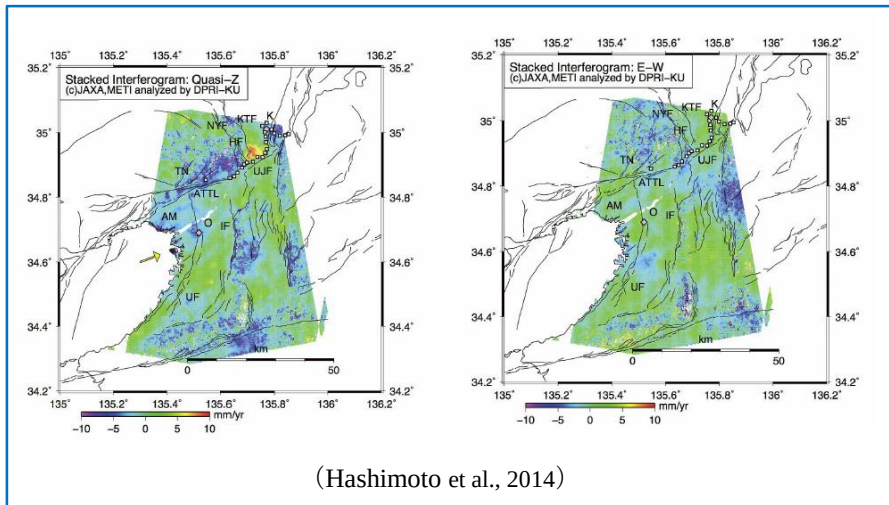


2018 Northern Osaka Earthquake Coseismic displacement

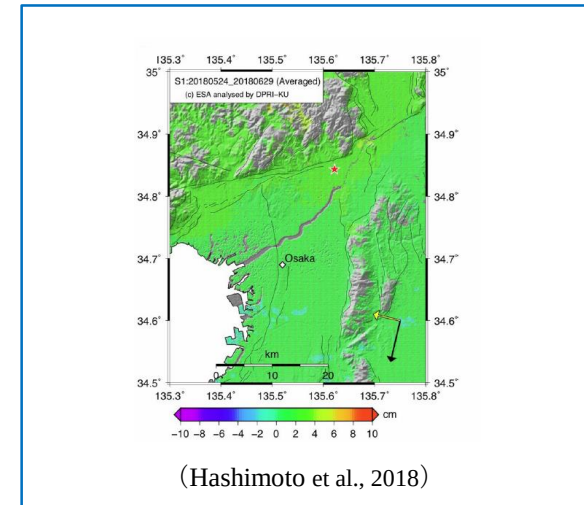


In Keihanshin area...

Annual displacement for the long term



Coseismic displacement



2007

2010

2018

Northern Osaka Earthquake

Hashimoto's achievements

- ✓ First InSAR analysis in Keihanshin area
- ✓ Lots of analysis in various time periods

Issue

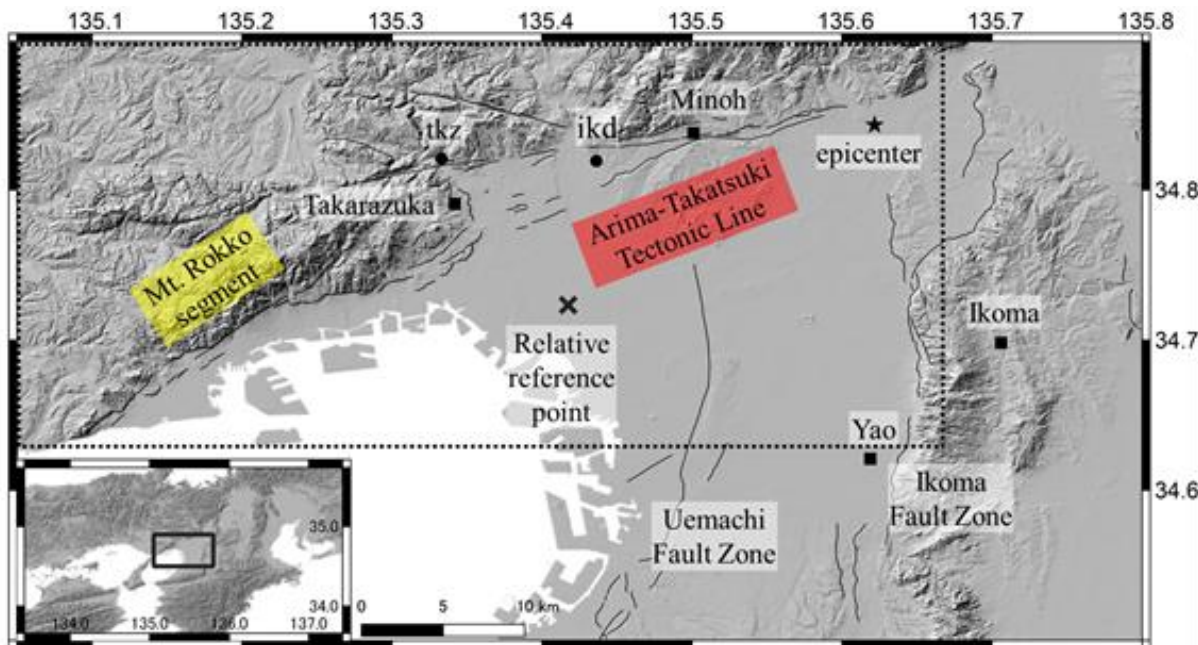
What is the specific mechanism of surface displacement?

Purpose

To detect surface displacement around active fault
by application of a new analysis method, PSInSAR analysis

1. Target area (around active faults)

2. PSInSAR analysis



- Active Faults
- ★ 2018 Northern Osaka earthquake epicenter
- ✕ Analysis relative reference point
- GNSS observation point
- Groundwater level observation points

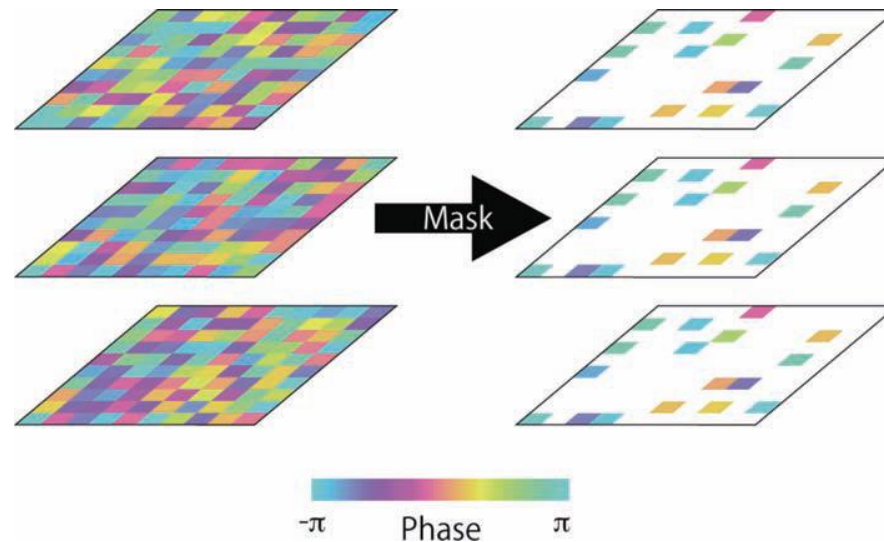
To detect annual surface displacement by using 72 dataset in 2015~2019

- in the Arima-Takatsuki Fault Zone, which is the fault near the epicenter of the 2018 Northern Osaka Earthquake,
- near the Mt. Rokko active segment

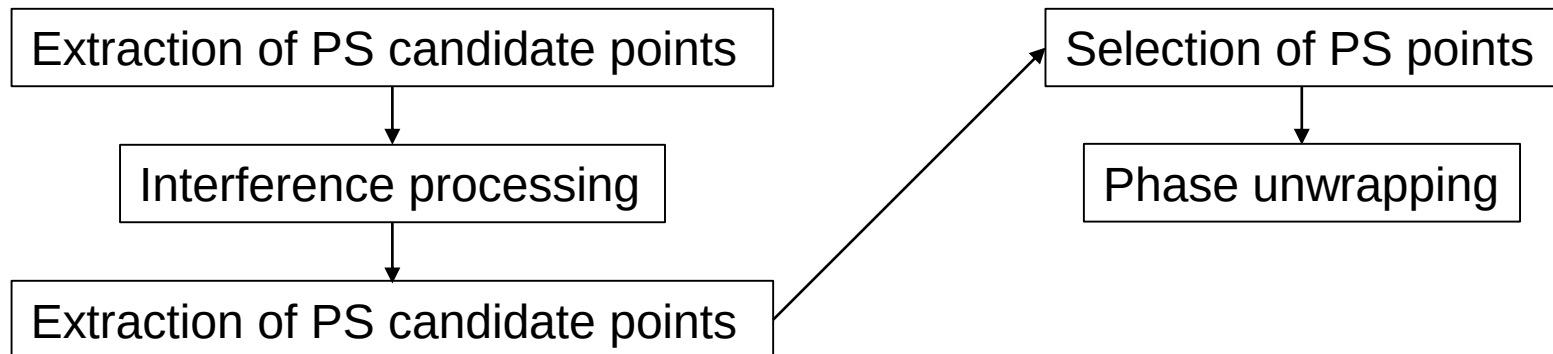
1. Target area (around active faults)

2. PSInSAR analysis

The observation error can be reduced by statistically extracting observation points with low noise.

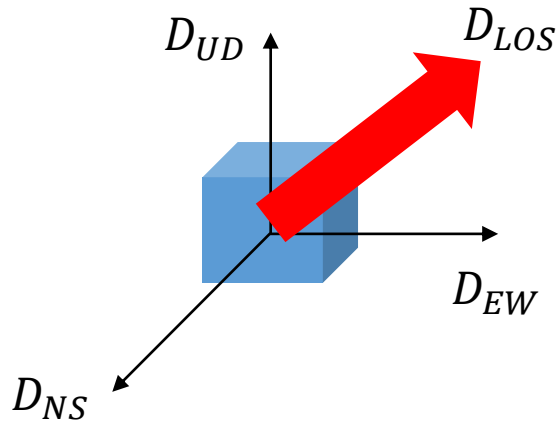


(Fukushima 2011)

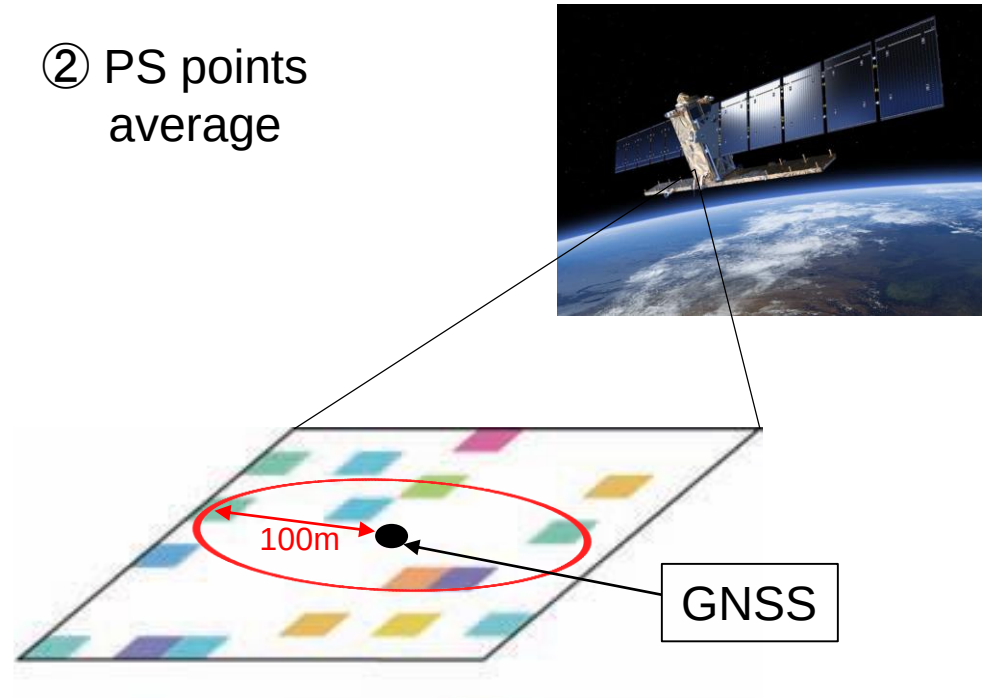


Comparison with GNSS

- ① GNSS observation points conversion



- ② PS points average



$$\textcircled{1} D_{LOS} = [-\cos \alpha \sin \theta \quad \sin \alpha \sin \theta \quad \cos \theta][D_{EW} \quad D_{NS} \quad D_{UD}]^T$$

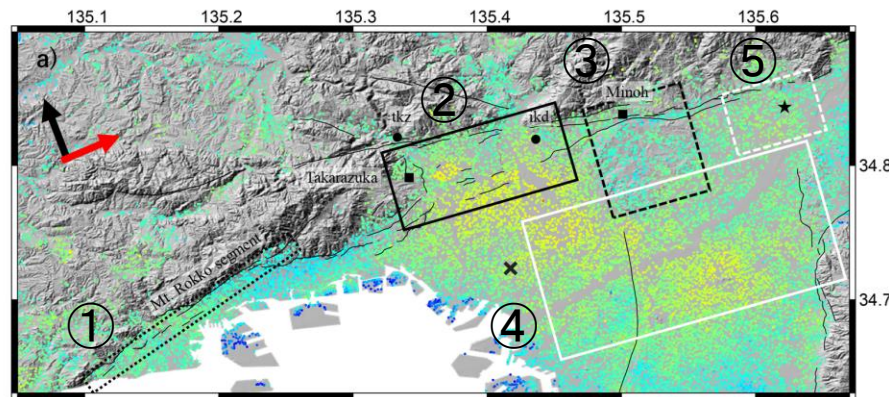
$$\textcircled{2} \sum_i^N \frac{Disp_{ps}}{N} \quad (\text{Within a radius of 100m})$$

Results

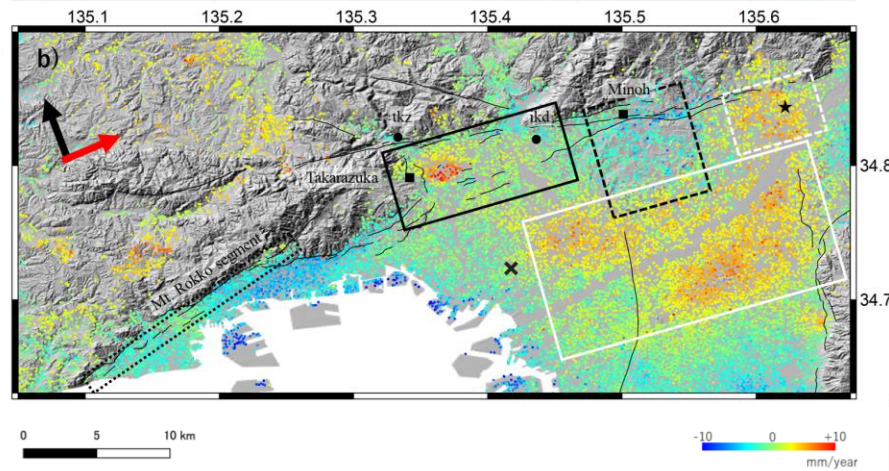
1. Surface displacement trends have clearly changed in some areas between the pre- and post-earthquake periods.
2. Comparison of analysis results with GNSS shows good agreement and validation.

Result 1

Pre-earthquake
20150428~
20180605



Post-earthquake
20170722~
20190425



Average displacement



-2.4 1.6 -0.8 1.5 0



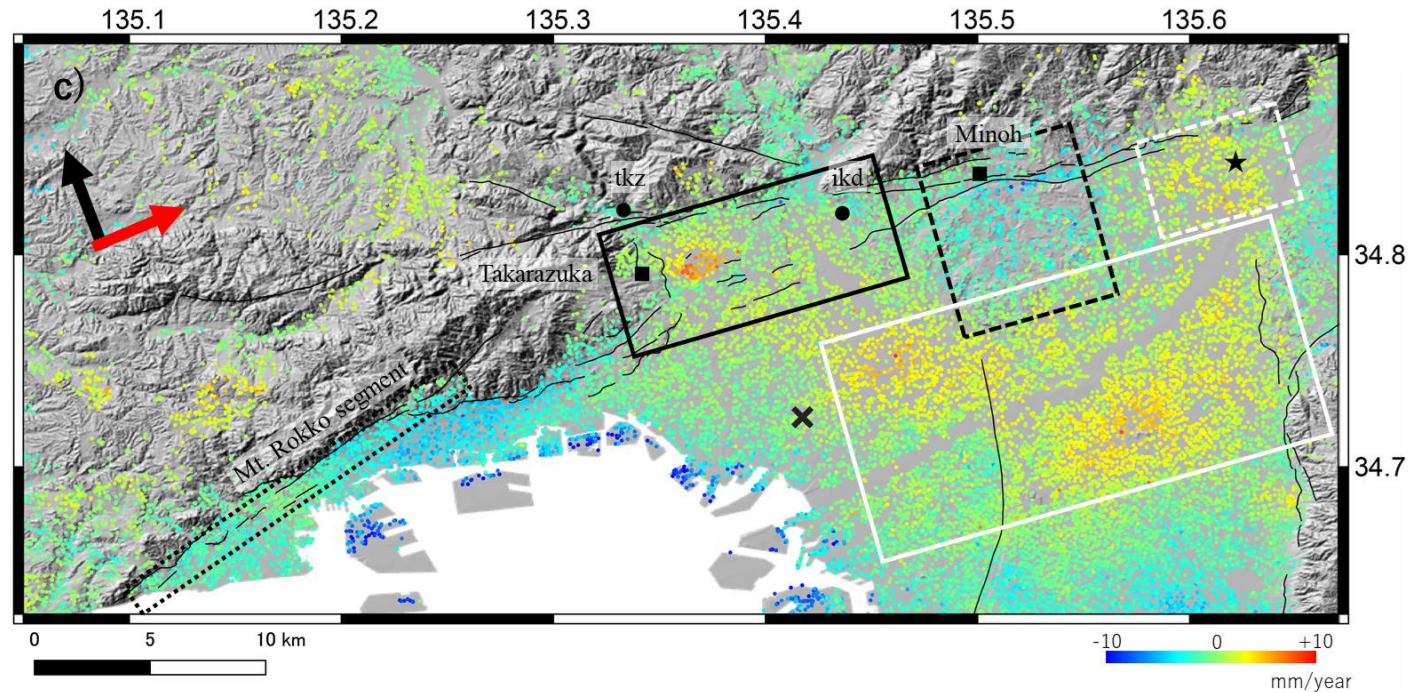
-2.9 6~10 -4.8 2~4 4~7

→ Large absolute value

Result 2

All time period

20150428~
20190425



Validation test

$\text{GNSS}([\text{Takarazuka}, \text{Ikoma}, \text{Yao}] - \text{Minoh}) - \text{PS}([\text{Takarazuka}, \text{Ikoma}, \text{Yao}] - \text{Minoh})$
 $= 1.05, 2.99, 3.15 \text{ [mm/year]} < 5 \text{ [mm/year]}$

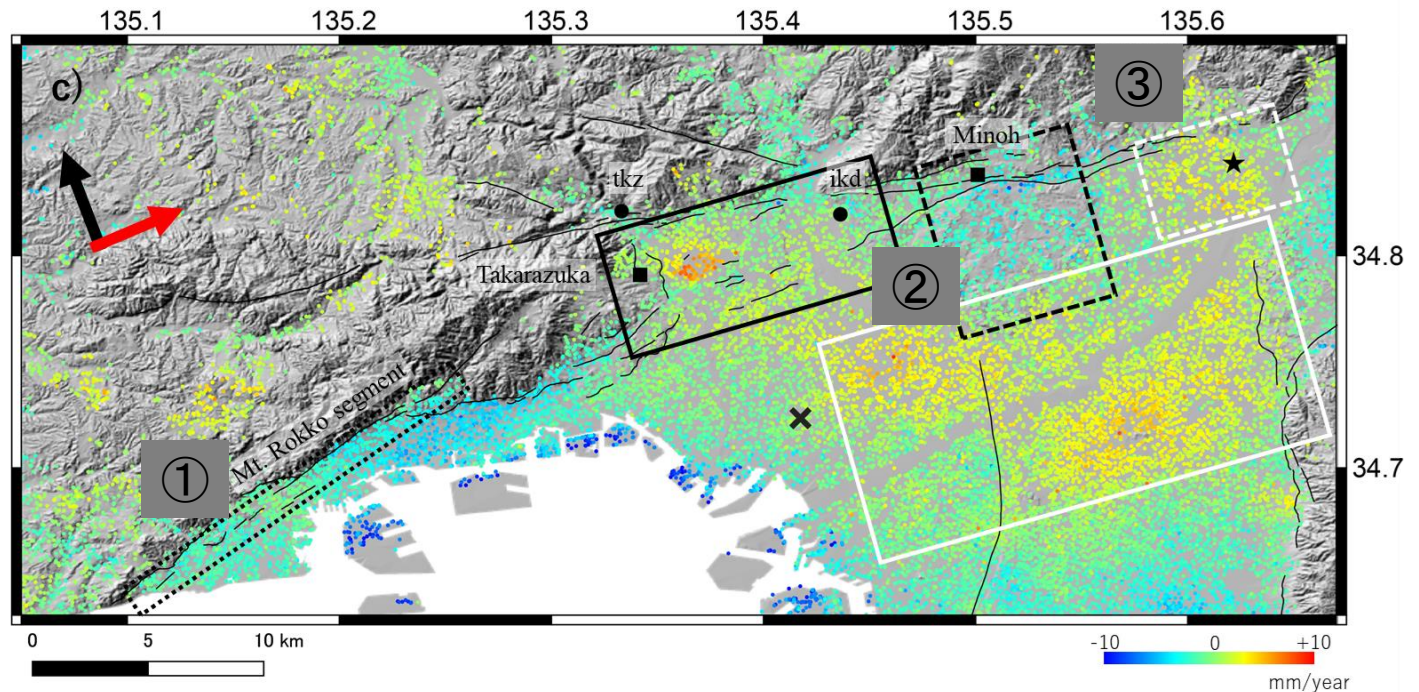
(Ex) Ishitsuka et al., 2016 shows 2 [mm/year]

Area for consideration

- ① Mt. Rokko active segment
- ② Arima Takatsuki Fault Zone 1, 2 and Osaka plain
- ③ Around 2018 Northern earthquake epicenter

All time period

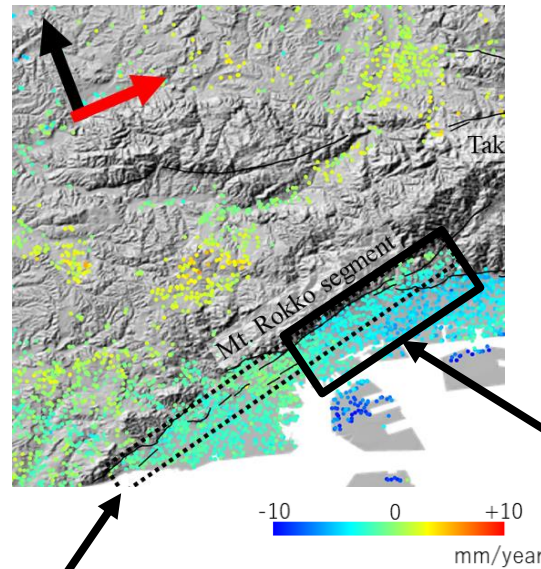
20150428~
20190425



① Mt.Rokko active segment

All time period

20150428~
20190425

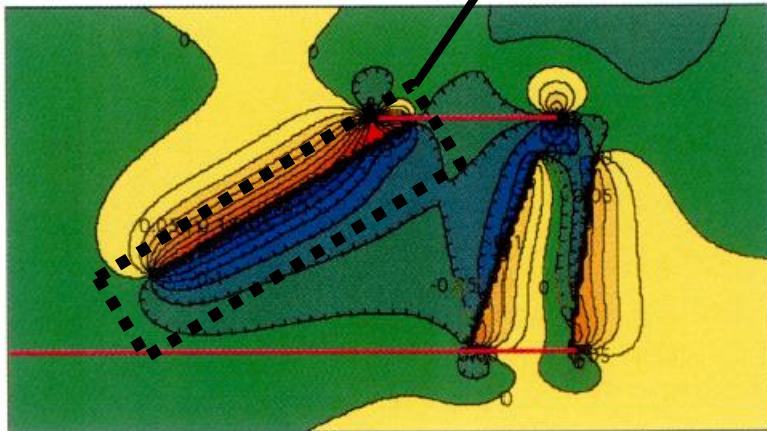


Average displacement

-2.52 mm/year

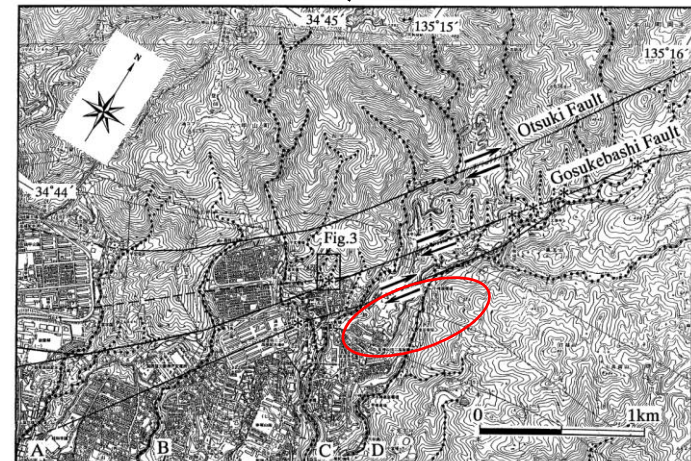
Subsidence or
Eastward displacement
for fault movement

Kusumoto et al., 2001



→ Subsidence

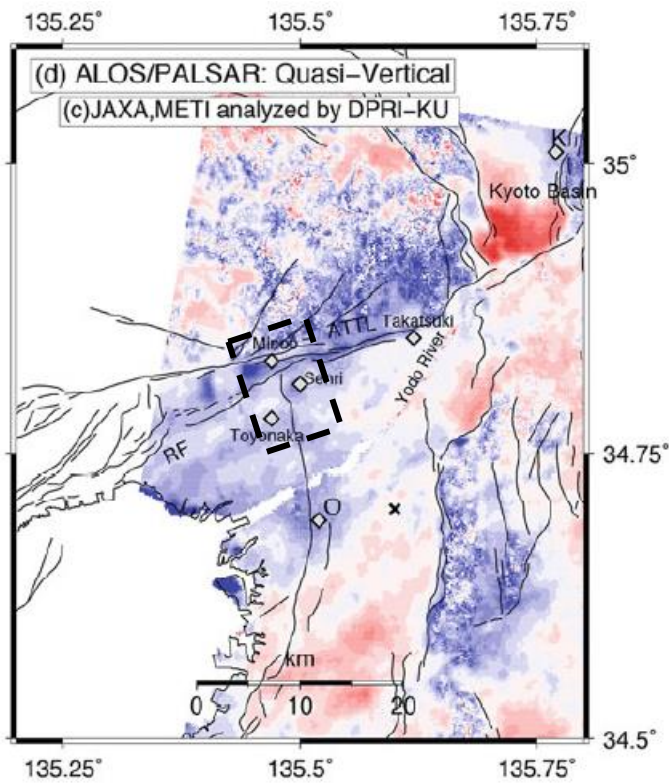
Lin et al., 1998



→ Westward displacement

② Arima Takatsuki fault zone 1

Hashimoto 2018
2007~2010

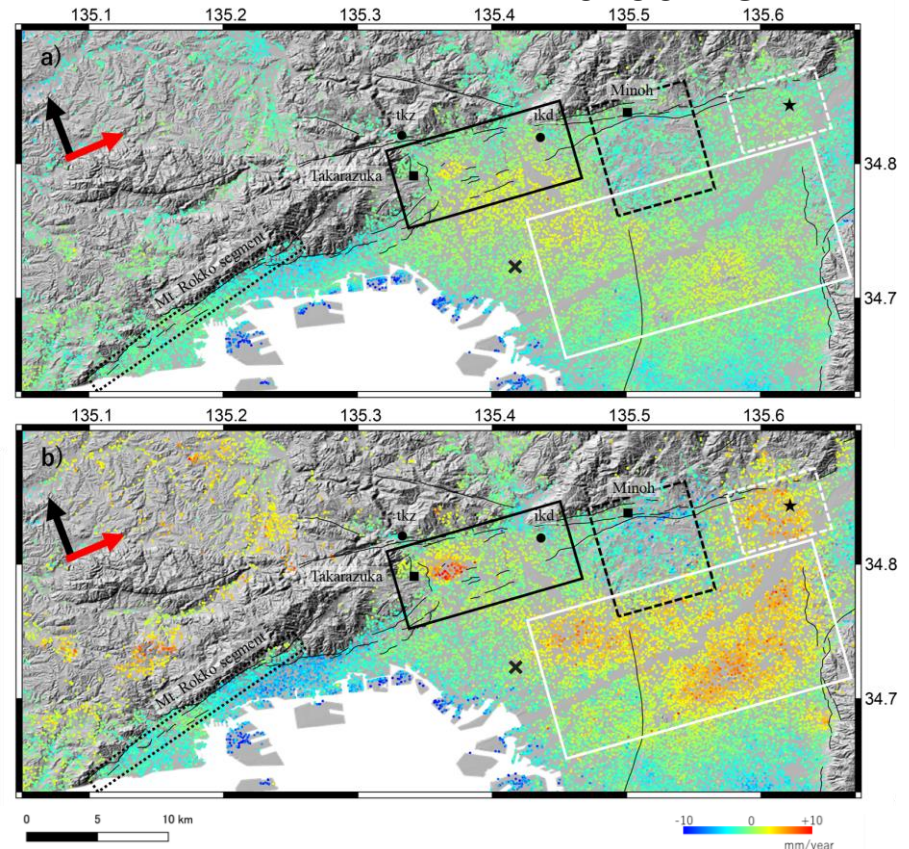


top

Pre-earthquake
20150428~
20180605

bottom

Post-earthquake
20170722~
20190425



Subsidence : -5mm/year



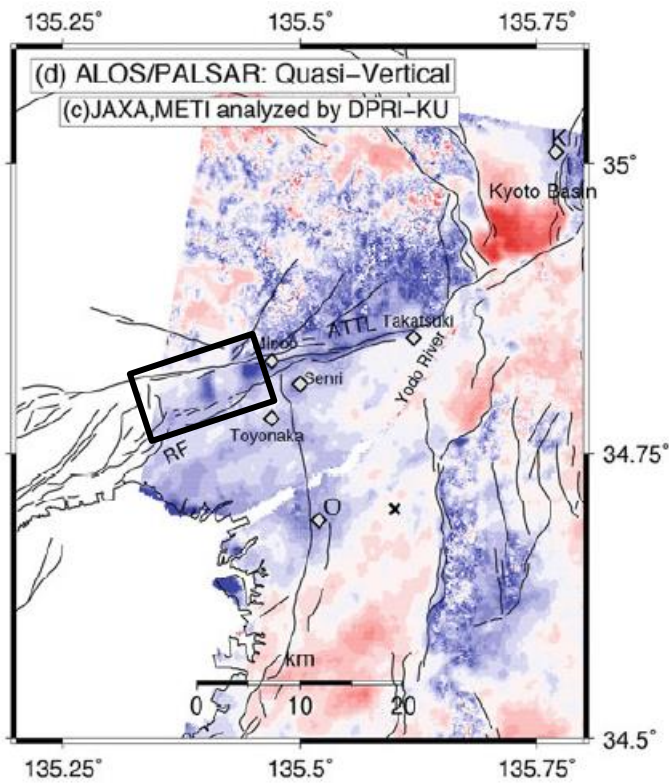
Similar



LOS direction displacement : -1~5mm/year

② Arima Takatsuki fault zone 2

Hashimoto 2018
2007~2010

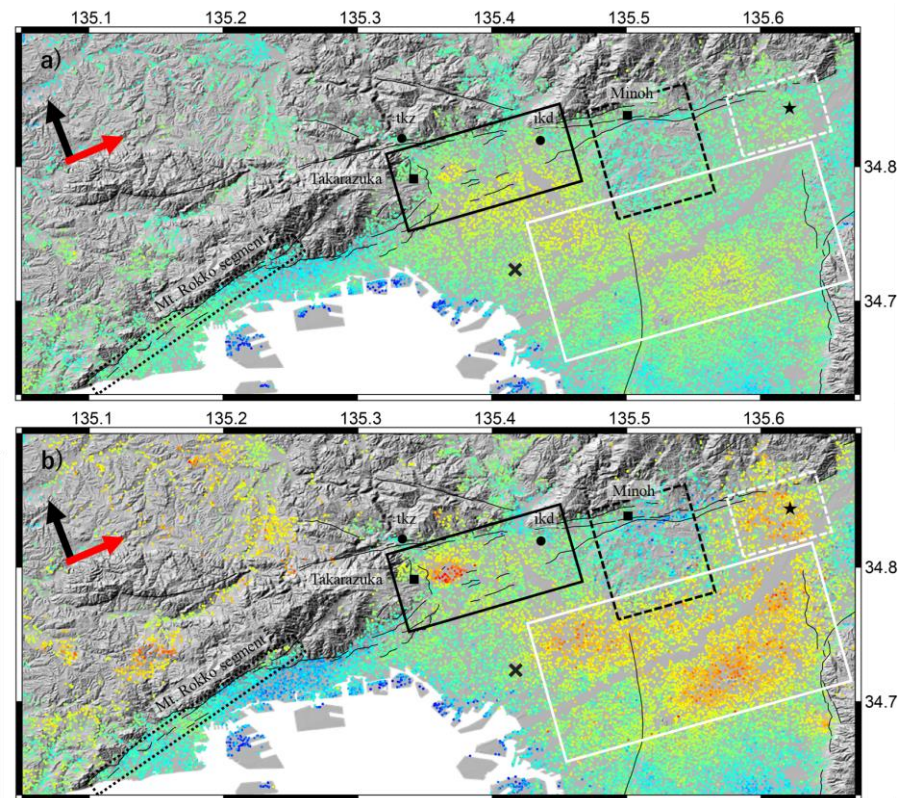


top

Pre-earthquake
20150428~
20180605

bottom

Post-earthquake
20170722~
20190425



Subsidence



Reverse



Uplift or westward displacement

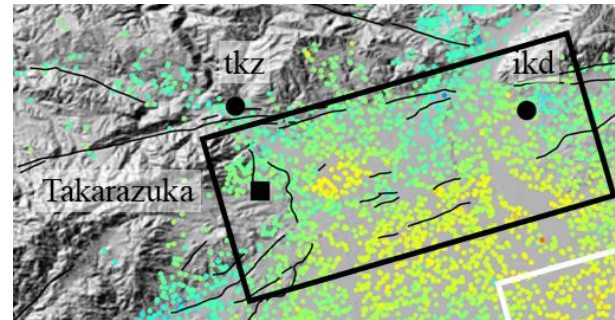
② Arima Takatsuki fault zone 1,2 mechanism



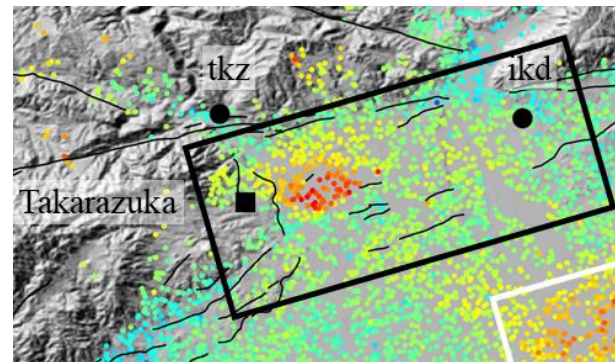
Hashimoto's suggestion : Surface displacement happens for groundwater

Surface displacement

Pre-earthquake
20150428~
20180605



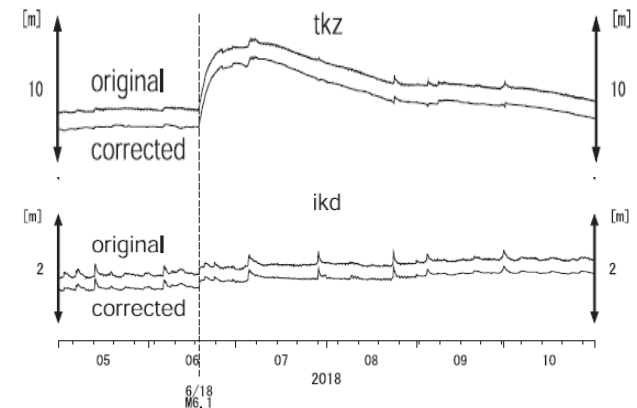
Post-earthquake
20170722~
20190425



-10 0 +10
mm/year

Uplift or western displacement

Groundwater level



Kitagawa et al

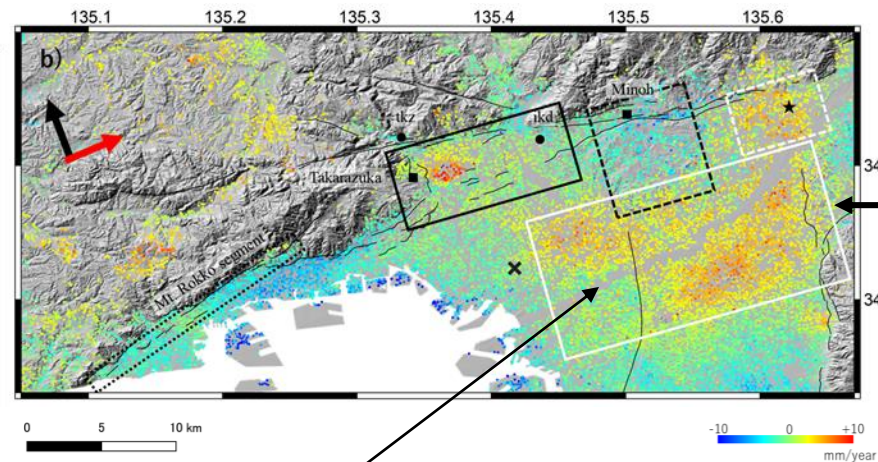
Uplift

Suggestion Possibility that the groundwater level is causing surface displacements.

② Osaka Plain

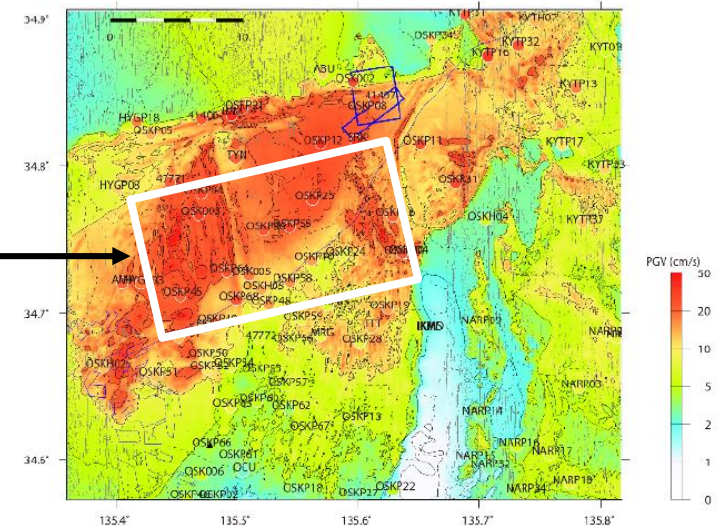
Elkhoury et al., 2006 : Permeability $K \propto$ peak ground velocity (PGV)

Annual surface displacement



Yodo River

PGV simulation



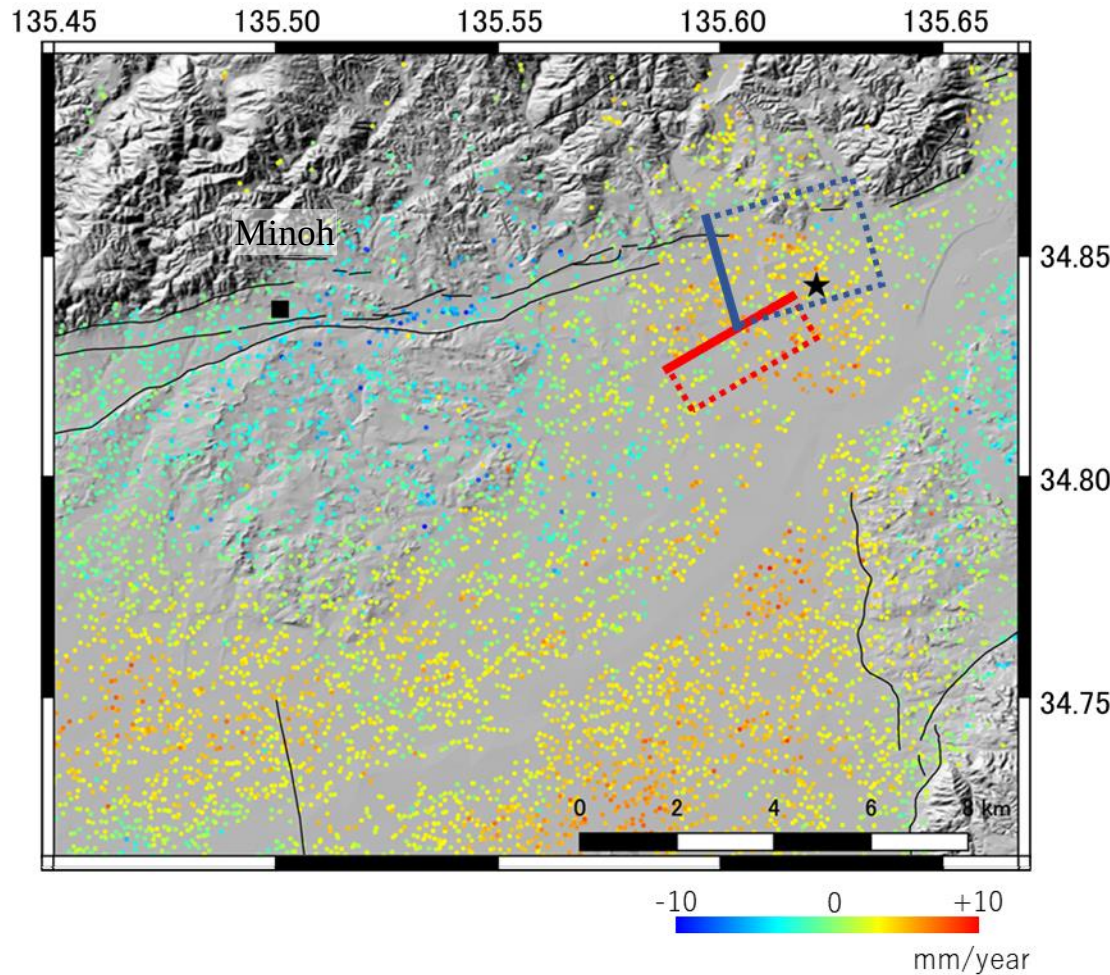
Sekiguchi et al., 2019

Suggestion

PGV increase $\rightarrow$ Permeability increase $\rightarrow$ Inflow of river water

$\rightarrow$ uplift surface displacement

③ Around 2018 Northern earthquake epicenter



Surface displacement

Uplift or **Westward** displacement

Asano et al., 2019

Earthquake source fault model

Blue Fault

Thrust faulting

→ **Westward** displacement

Red Fault

Strike-slip faulting

→ **West-southwest** displacement

Suggestion

Possibility of displacement by earthquake fault

Conclusion

Results ✓ Estimation of surface displacement around faults
 ✓ Validation by comparison with GNSS

Facts 1. Subsidence near the Mt. Rokko active segment
 2. Subsidence or eastward displacement
 in the eastern part of the Minoh GNSS station

Suggestions 1. surface displacement in the wedge-shaped area
 is suggested to be caused by groundwater level
 changes
 2. groundwater level changes may have caused
 surface displacement considered to be uplift
 in the wide area between the IFZ and UFZ
 3. slip of the source fault may have caused
 surface displacement around the epicenter

Appendix

Annual displacement calculation method

After

Least-squares method

Linear equation $y = a * x$



$$d = G * m$$

$$\begin{bmatrix} y_1 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} [a]$$

$$E = (d - G * m)(d - G * m)^T \longrightarrow \text{minimum}$$

Average displacement (mm) $m_{est} = (G^T * G)^{-1} * G^T * d = a$

