A 3-D simulation of crustal deformation accompanied by subduction in the Tokai region, central Japan

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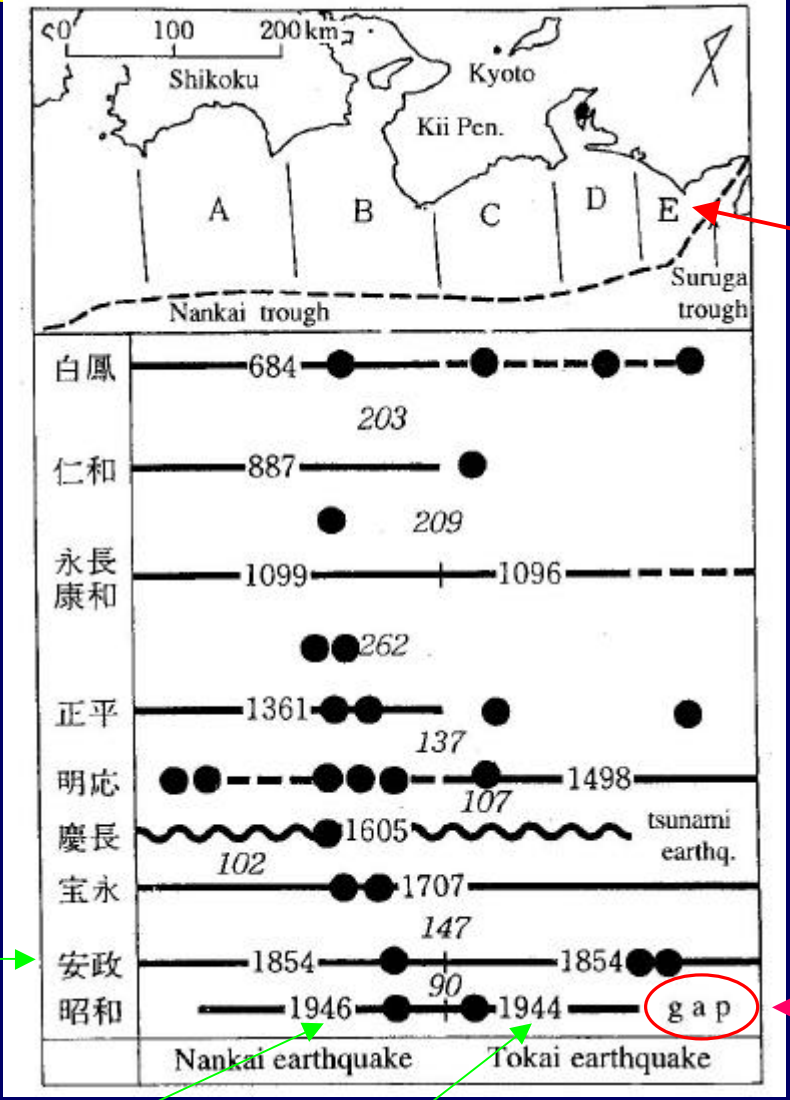
Contents

Space-time distribution of great earthquakes along the Nankai-Suruga trough



Tokai region

Ansei Tokai EQ

seismic gap

Nankai EQ

Tonankai EQ

after Ishibashi and Satake (1998)

Purpose of our study

Whether precursory changes for the anticipated Tokai earthquake could be observed or not.

Simulation study

1. Early studies

   Kato and Hirasawa (1999)

   Rate- and state-dependent friction law

   (Dieterich,1979; Ruina, 1983)

2. Problems

   2-D model

3. What's new in the present work

   3-D model with a curved plate interface

Model

Dislocation theory

radiation damping

$$t_i(t) = \sum_{j=1}^{N} K_{ij}(V_j^{pl} t - u_j(t)) - \frac{G}{2b}\frac{du_i(t)}{dt} \quad \text{---------- (1)}$$

where t :shear stress K_{ij} :elastic stiffness V^{pl} :plate velocity

t :time u:slip amount G :rigidity b :S wave speed

Rate- and state-dependent friction law

$$t_i(t) = m_i(t) s_i^{eff}$$

$$m_i(t) = m_* + q_i(t) + a_i \ln(V_i / V_*) \quad \text{---------- (2)}$$

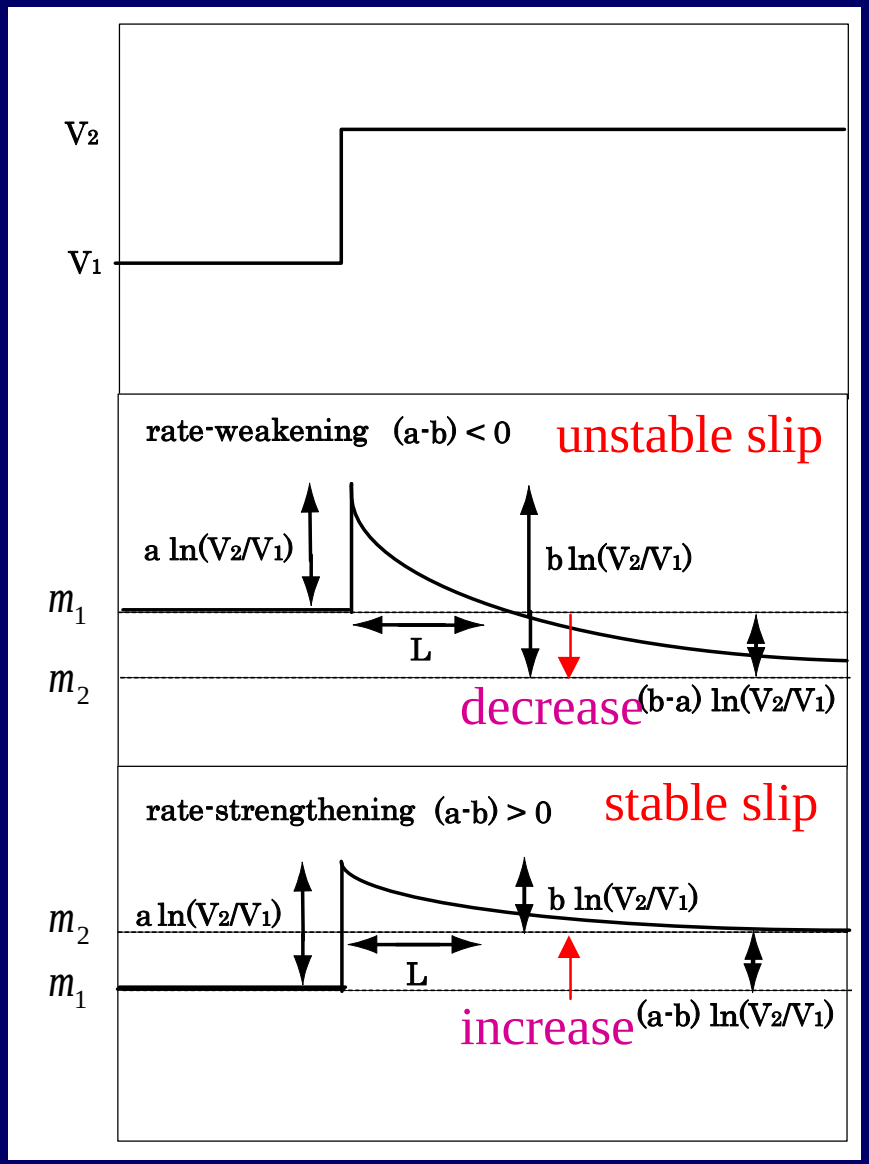
$$\frac{dq_i(t)}{dt} = -\frac{V_i(t)}{L_i}(q_i(t) + b_i \ln(V_i(t) / V_*))$$

where t :frictional force m :friction coefficient s :normal stress

q :state variable V :velocity a, b, L :friction parameters

after Dieterich (1979), Ruina (1983)

Rate- and state-dependent friction law



a-b<0

seismic zone

a-b>0

aseismic zone

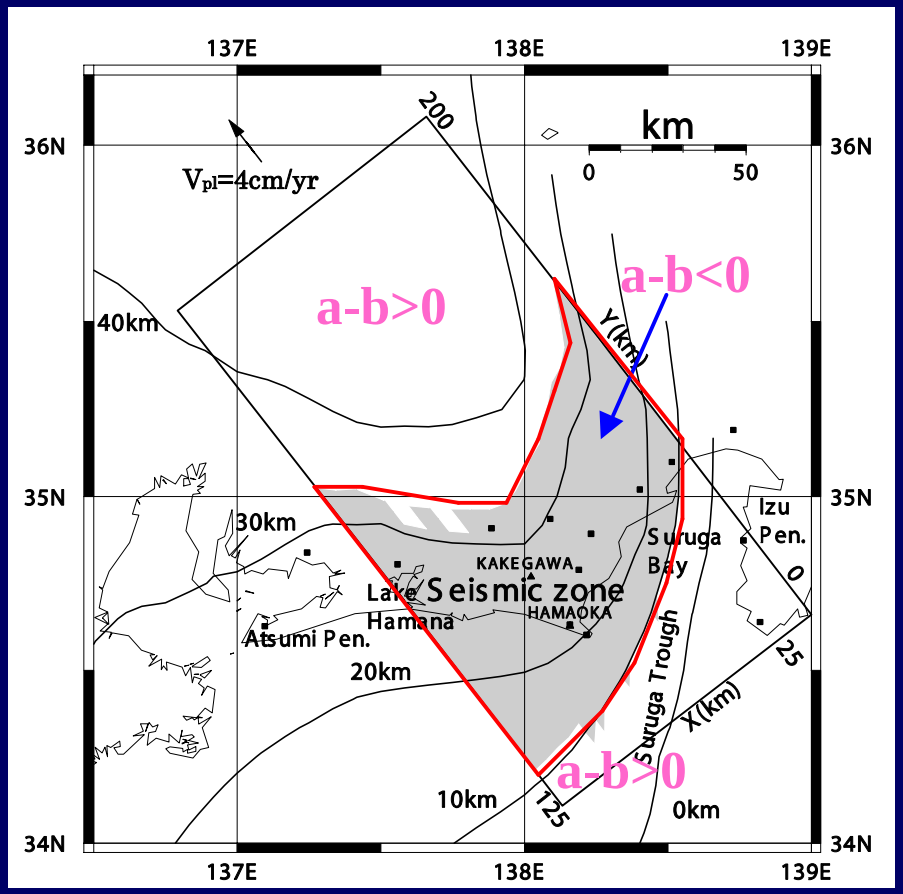
Dieterich (1979), Ruina (1983)

Geophysical constraints by observations

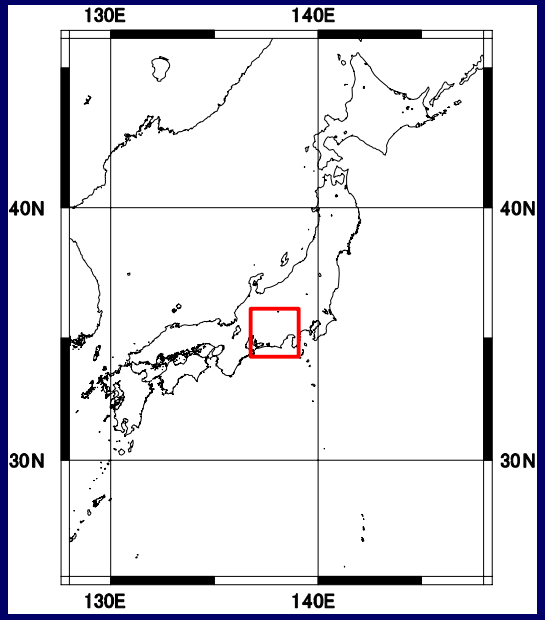
1. Plate configuration
   JMA hypocentral data — Harada et al. (1998)
2. Recurrence interval
   90-150 years — Ishibashi and Satake (1998)
3. Average seismic coupling coefficient
   0.5 (0-60km depth) — Peterson and Seno (1984)
4. Crustal deformation
   Leveling and GPS — Observation by GSI
5. Coupling region (Locked zone or seismic zone)
   10-30km depth — Matsumura (1997), Sagiya (1999) etc.
6. Plate velocity
   4cm/year — Seno et al. (1993)

Modeling of the plate interface

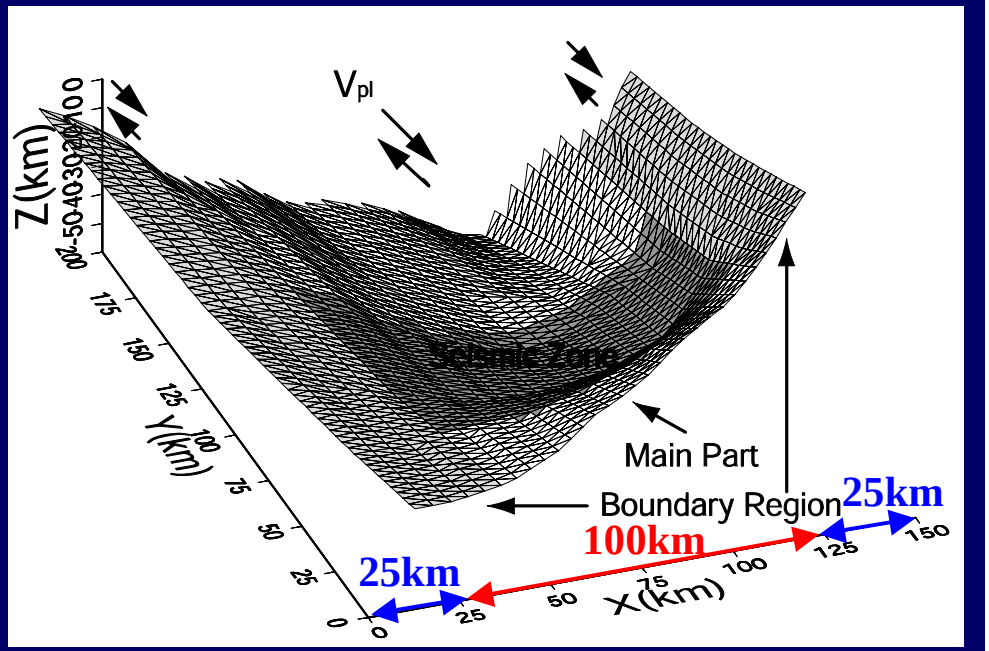
Tokai Region



$V_{pl} = 4cm/year$ Seno et al. (1993)

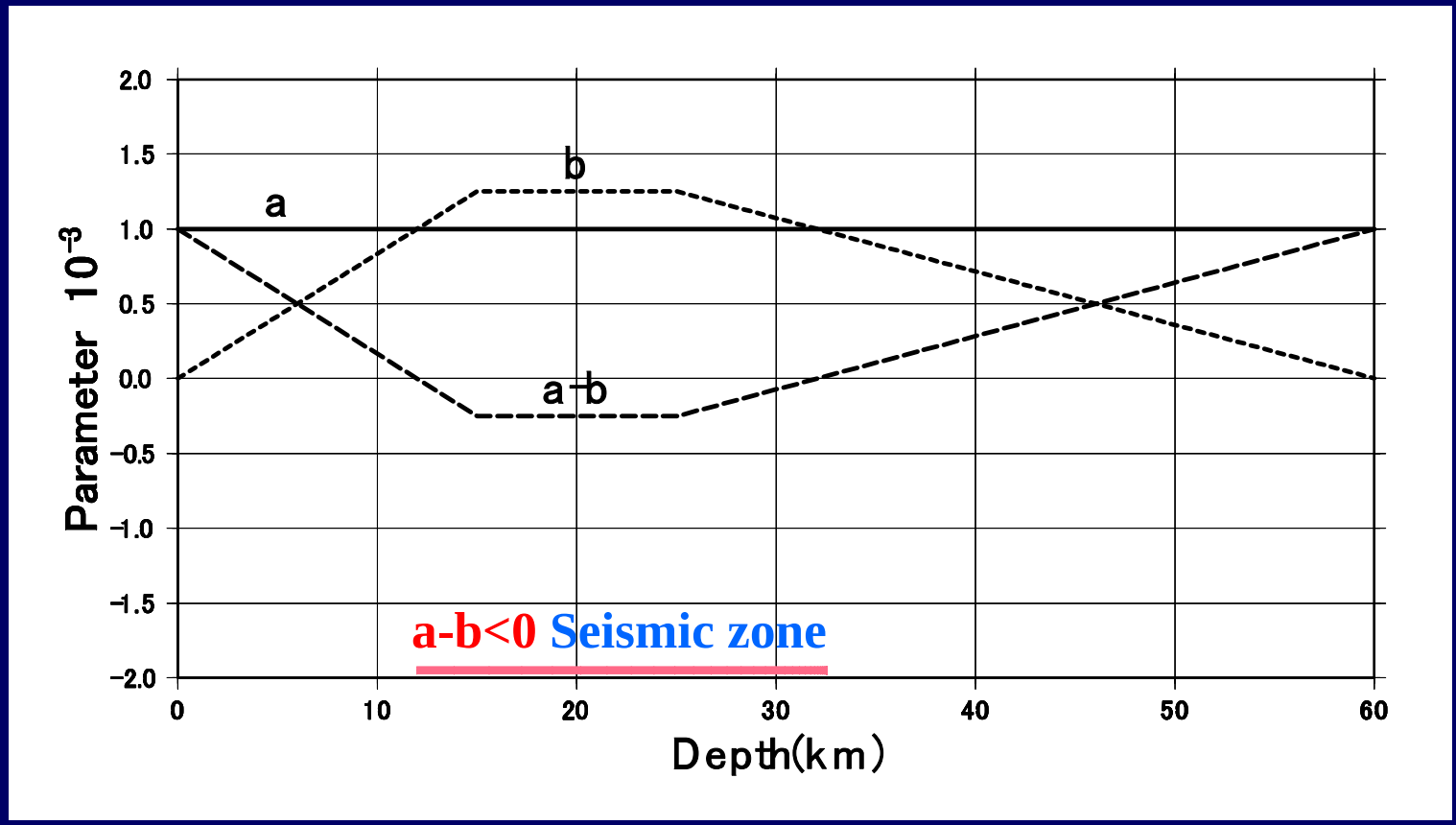


3D model



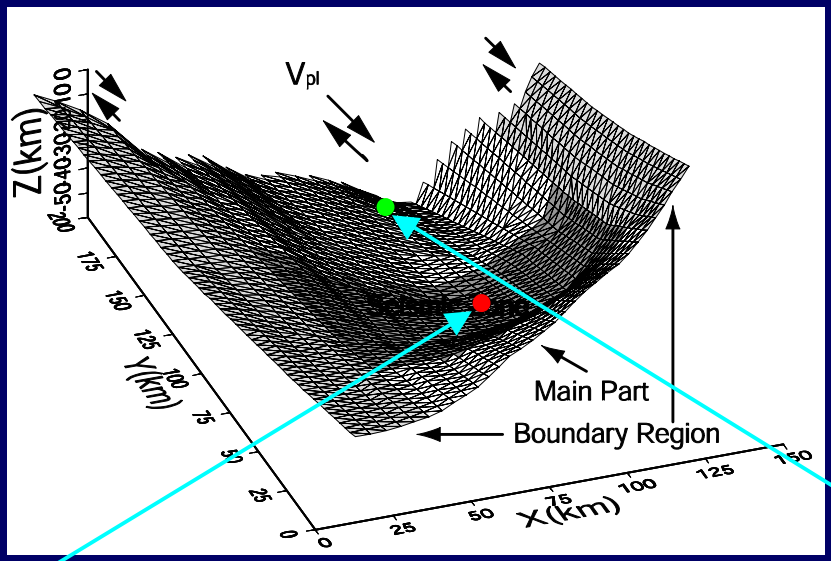
Viewed from Suruga Bay

Friction parameter



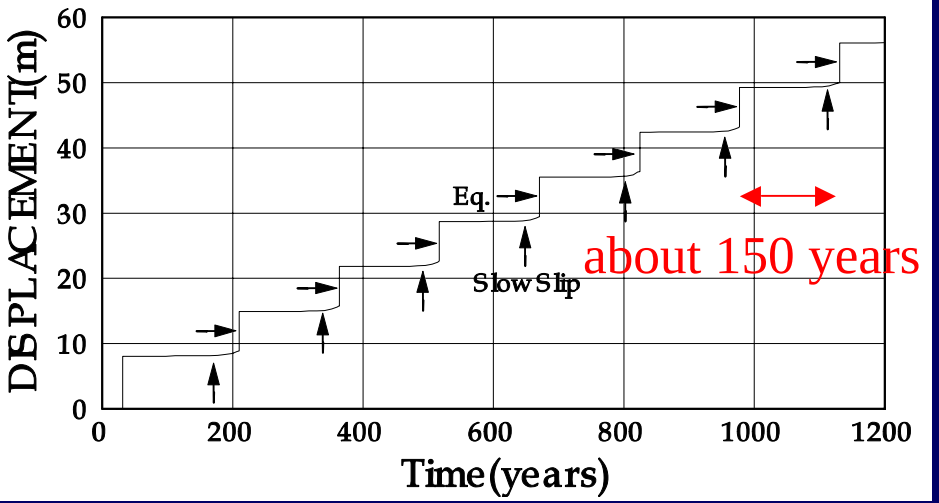
L=5cm

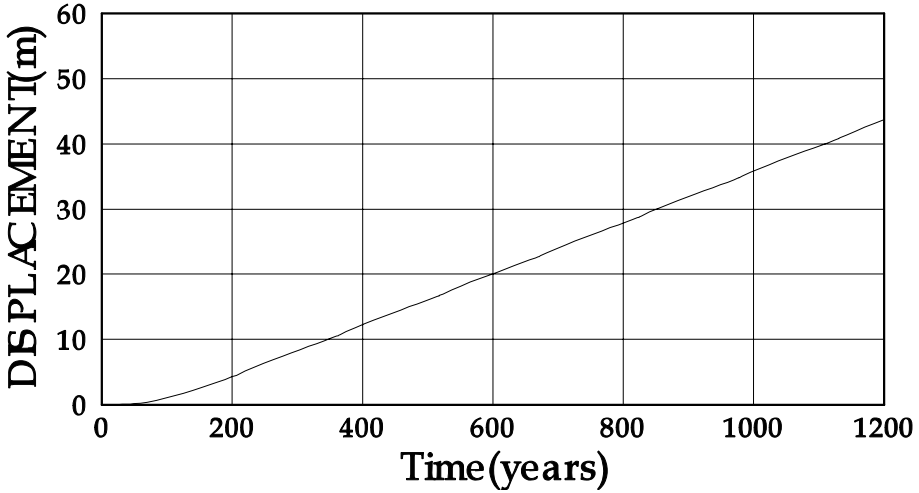
Time evolution of cumulative displacement



Seismic zone

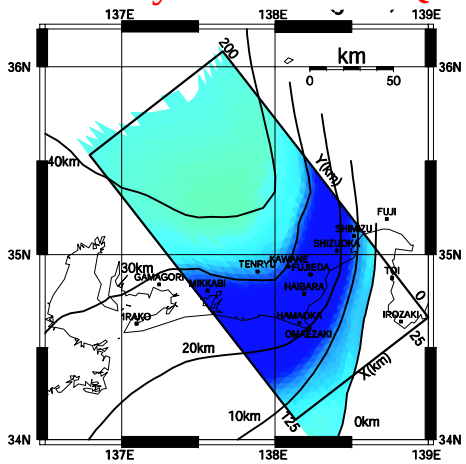
Aseismic zone



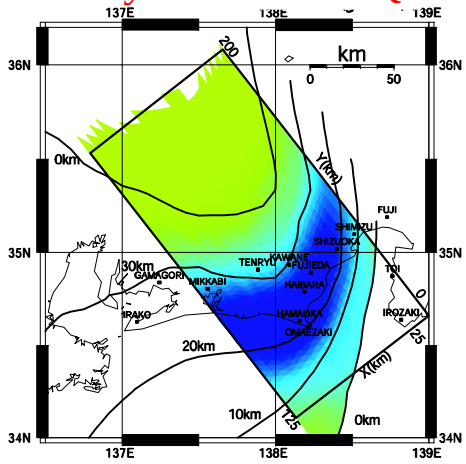


Displacement on the plate interface

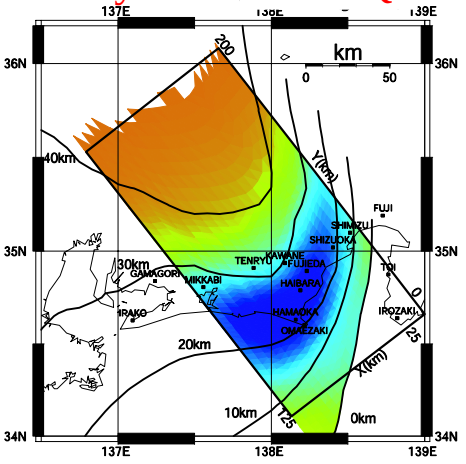
100 years before EQ



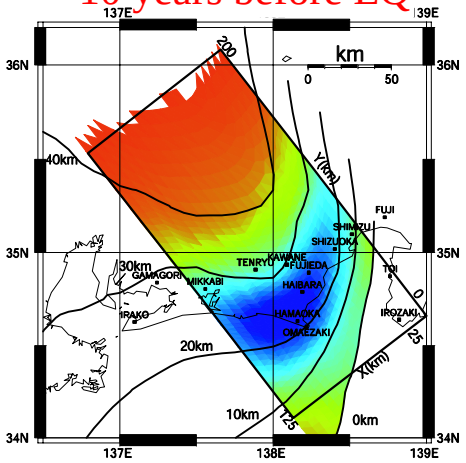
50 years before EQ



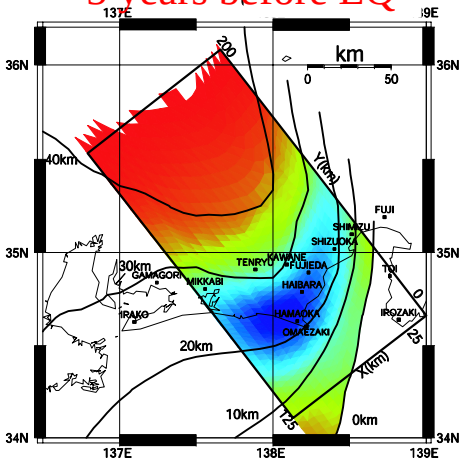
20 years before EQ



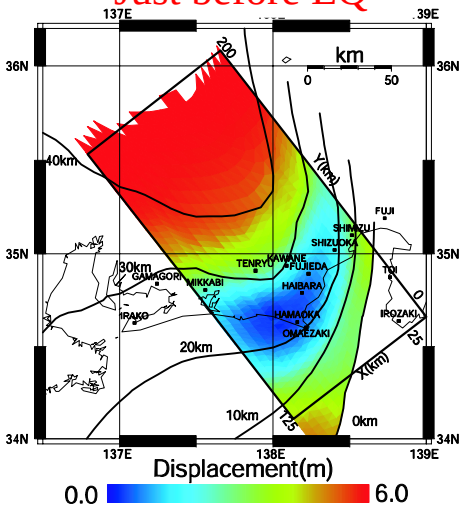
10 years before EQ



5 years before EQ

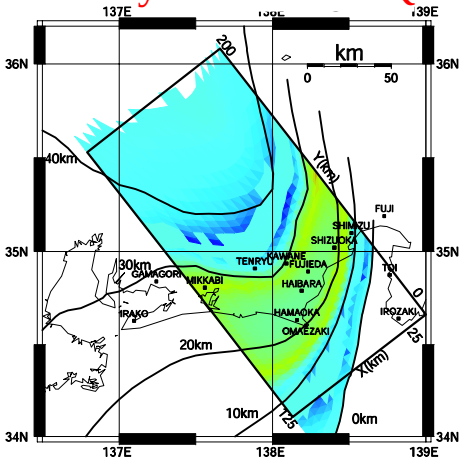


Just before EQ

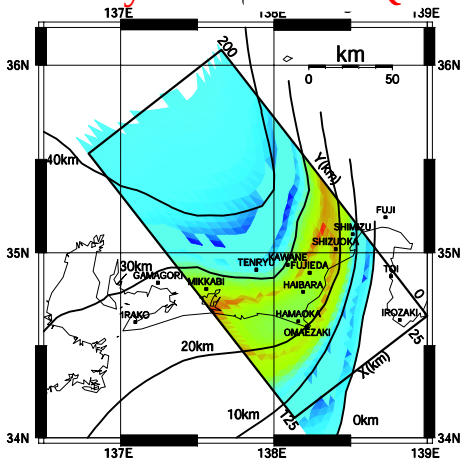


Shear stress on the plate interface

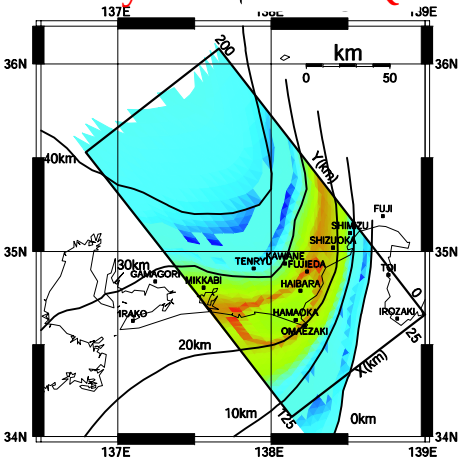
100 years before EQ



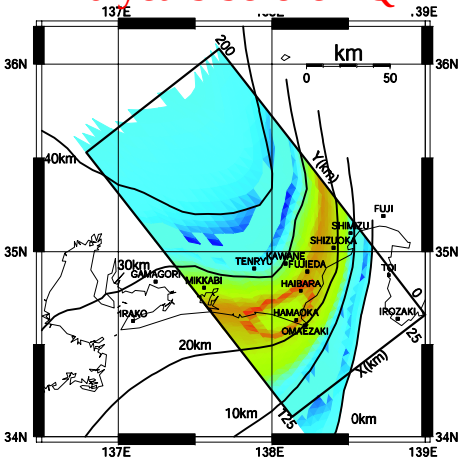
50 years before EQ



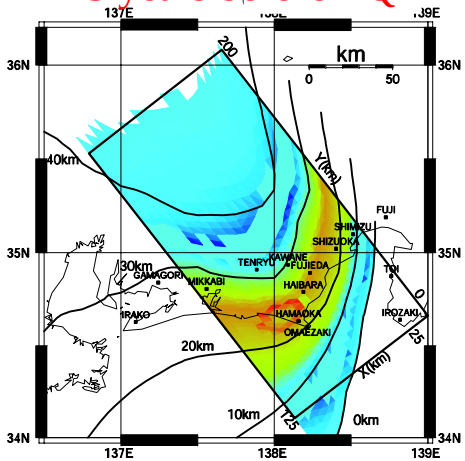
20 years before EQ



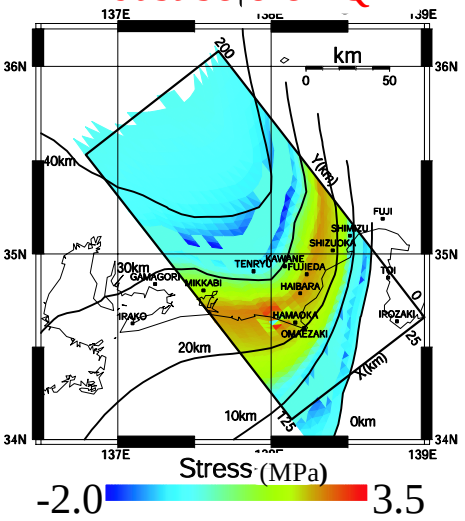
10 years before EQ



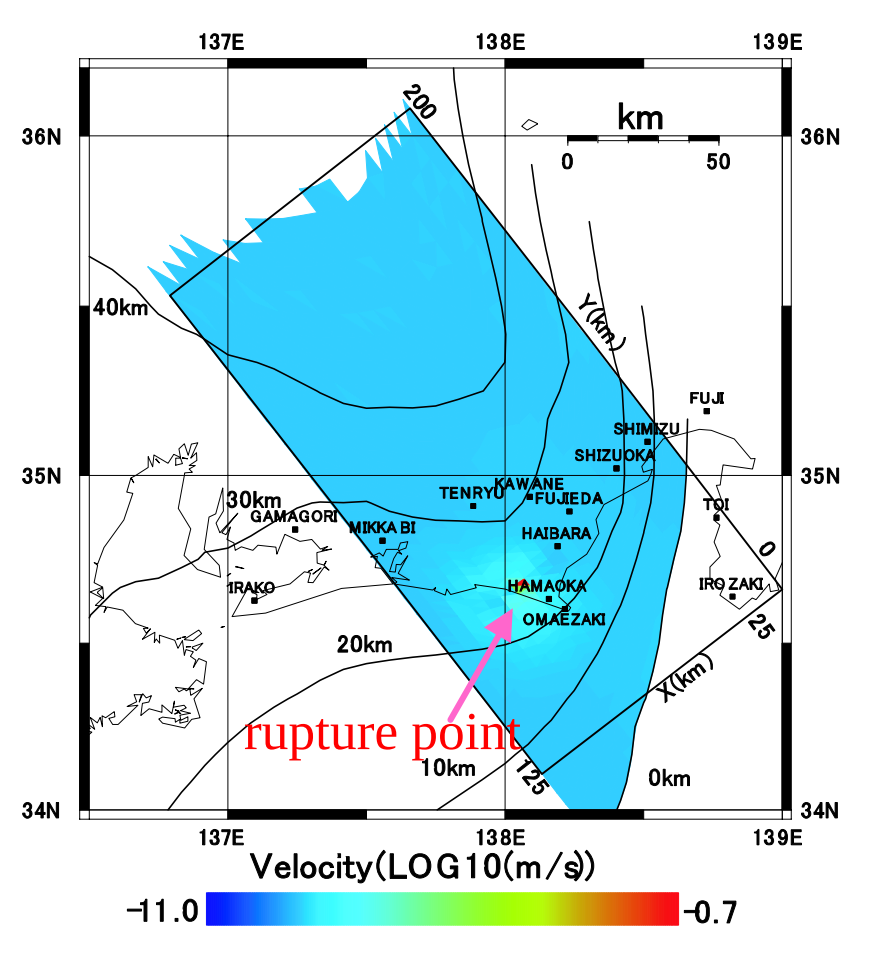
5 years before EQ



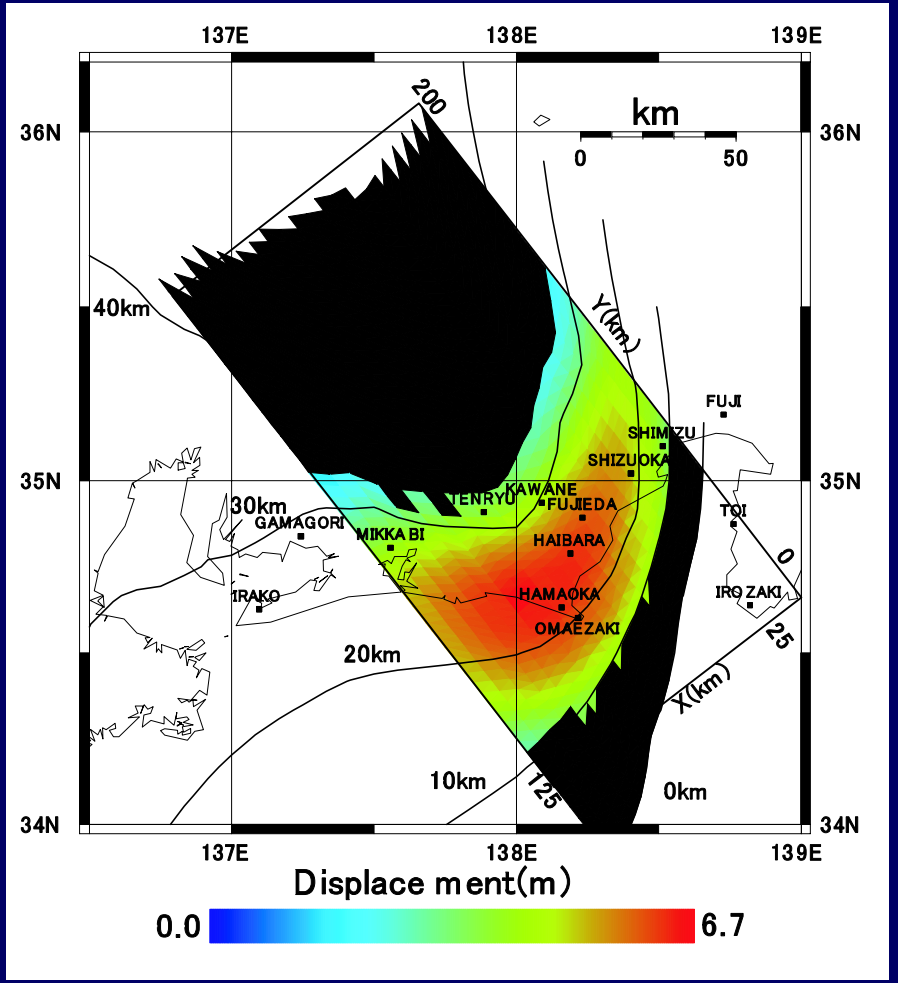
Just before EQ



Velocity just before EQ



Coseismic slip distribution

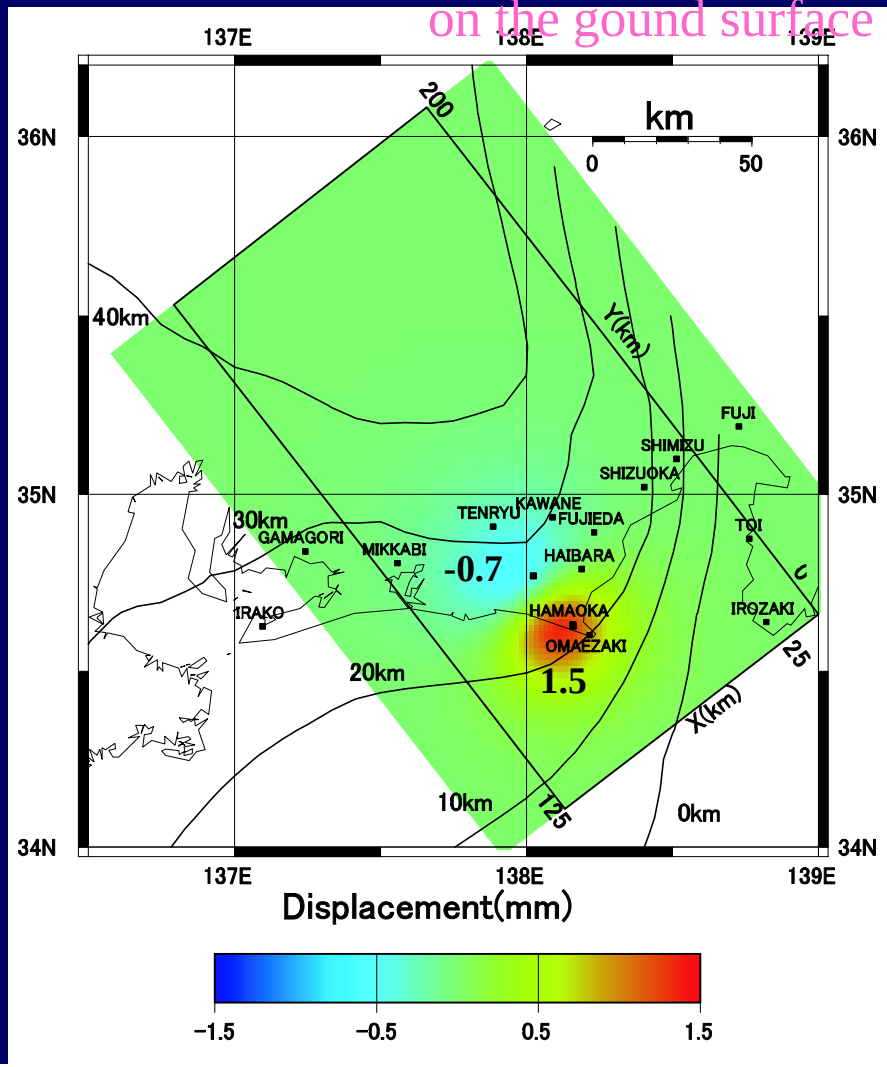


Average slip = 3.9m **Mw=8.0**

Level & Strain changes during one day before the earthquake

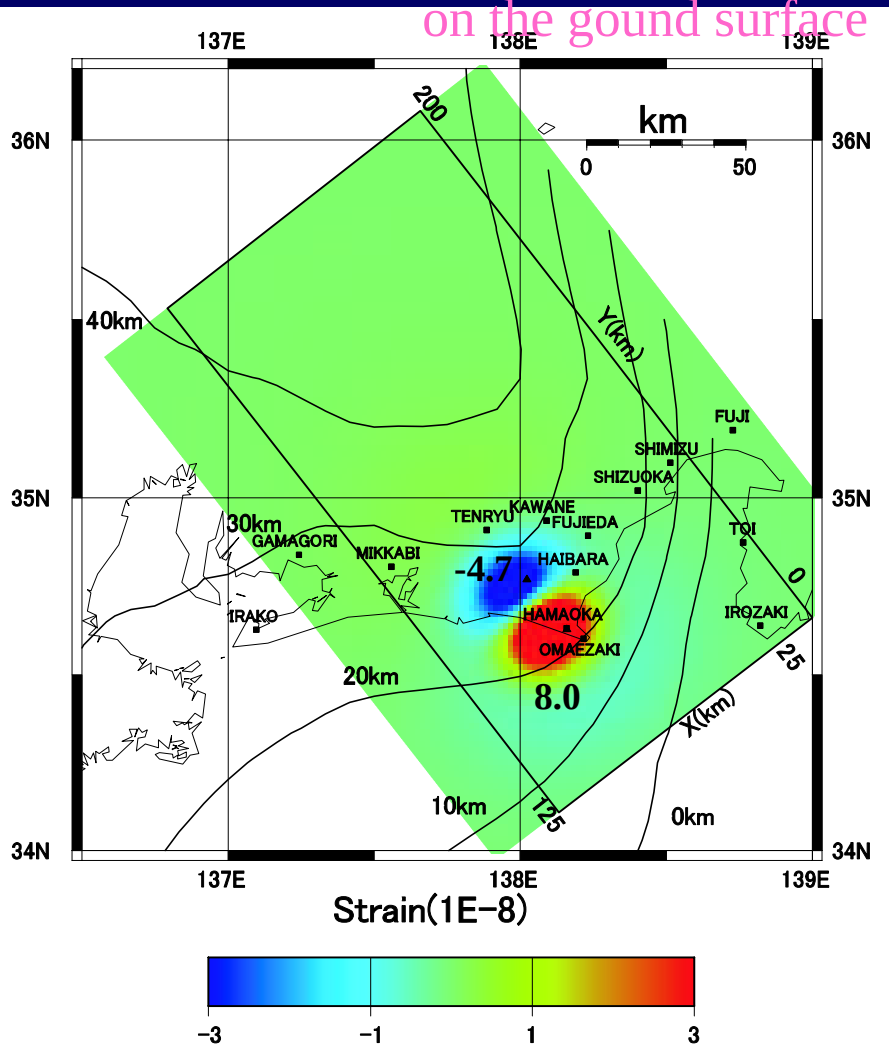
Level change

on the gound surface



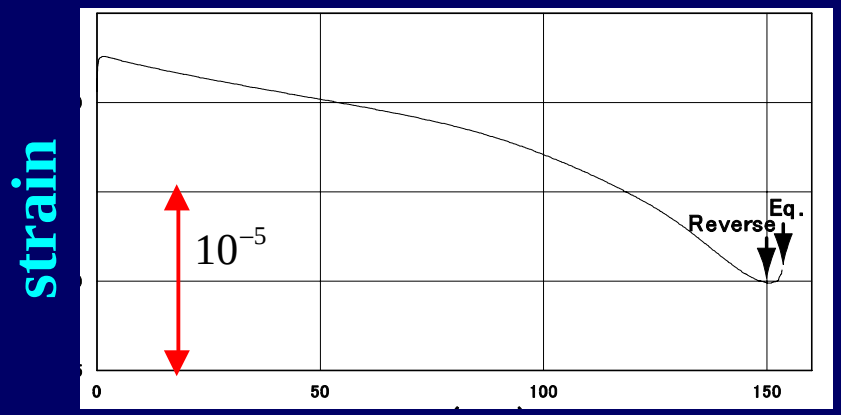
Strain change

on the gound surface

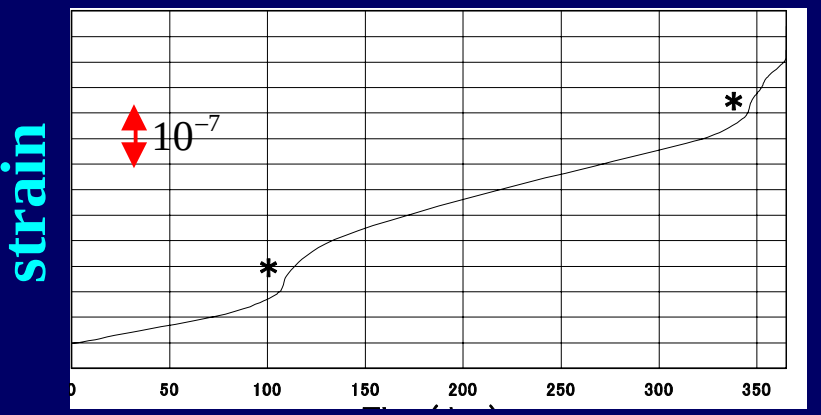


Temporal change of volumetric strain at Hamaoka station

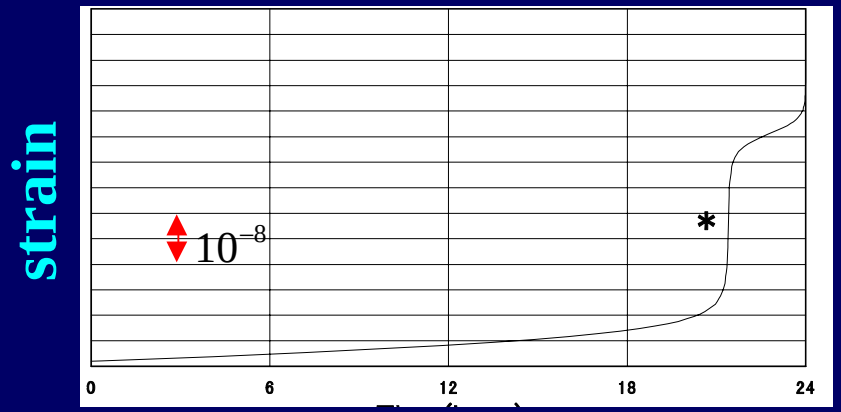
One Cycle



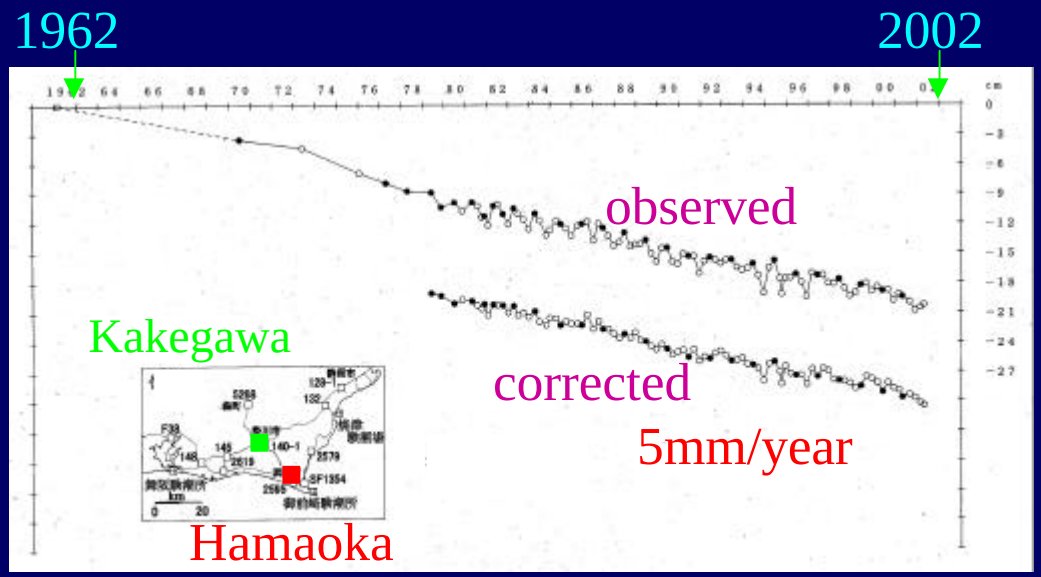
One year before EQ



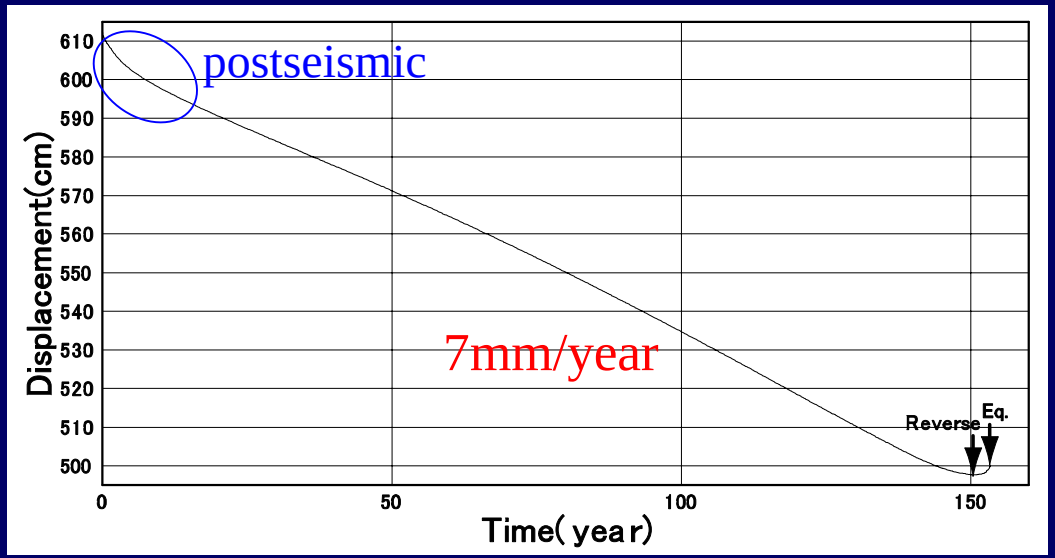
One day before EQ



Subsidence at Hamaoka relative to Kakegawa



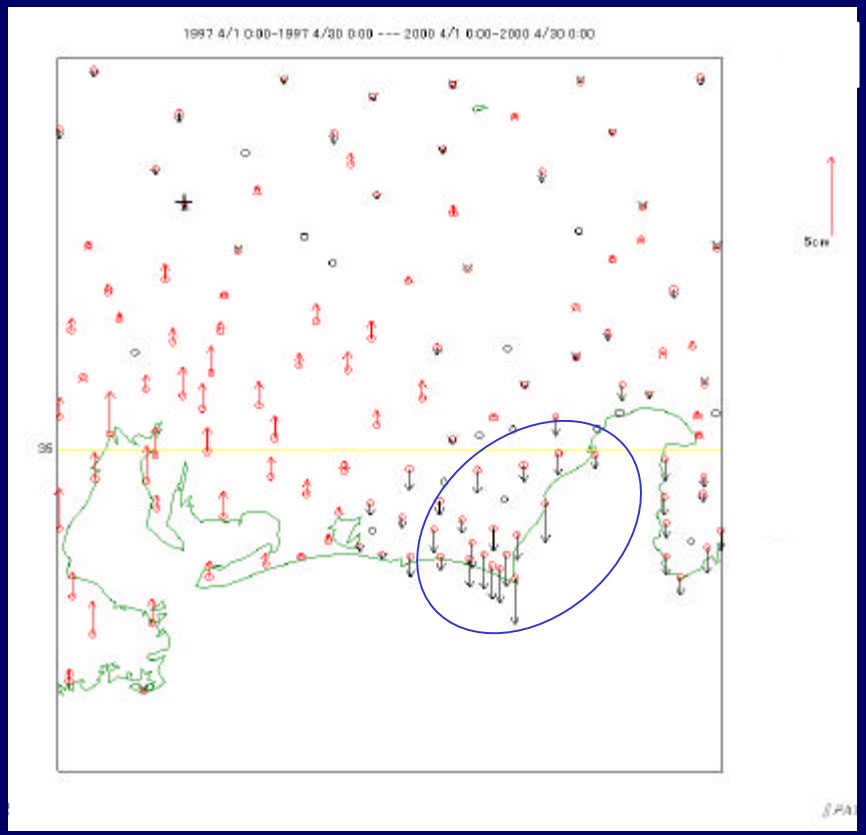
Observation by GSI



Simulation result

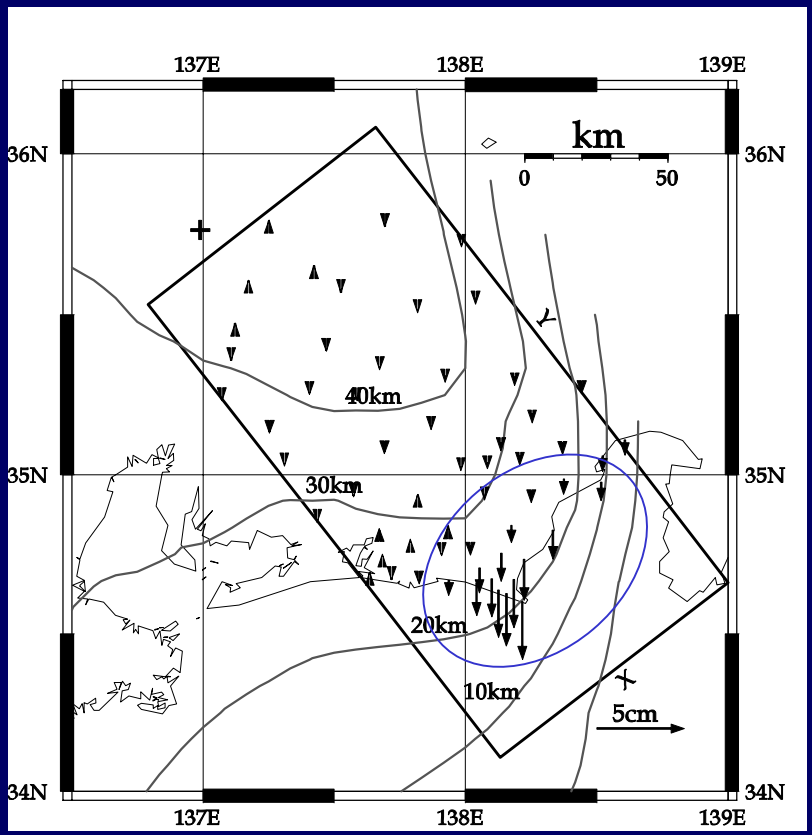
Comparison between GPS observation and simulation result for the vertical displacement

GPS observation



April 1997 – April 2000

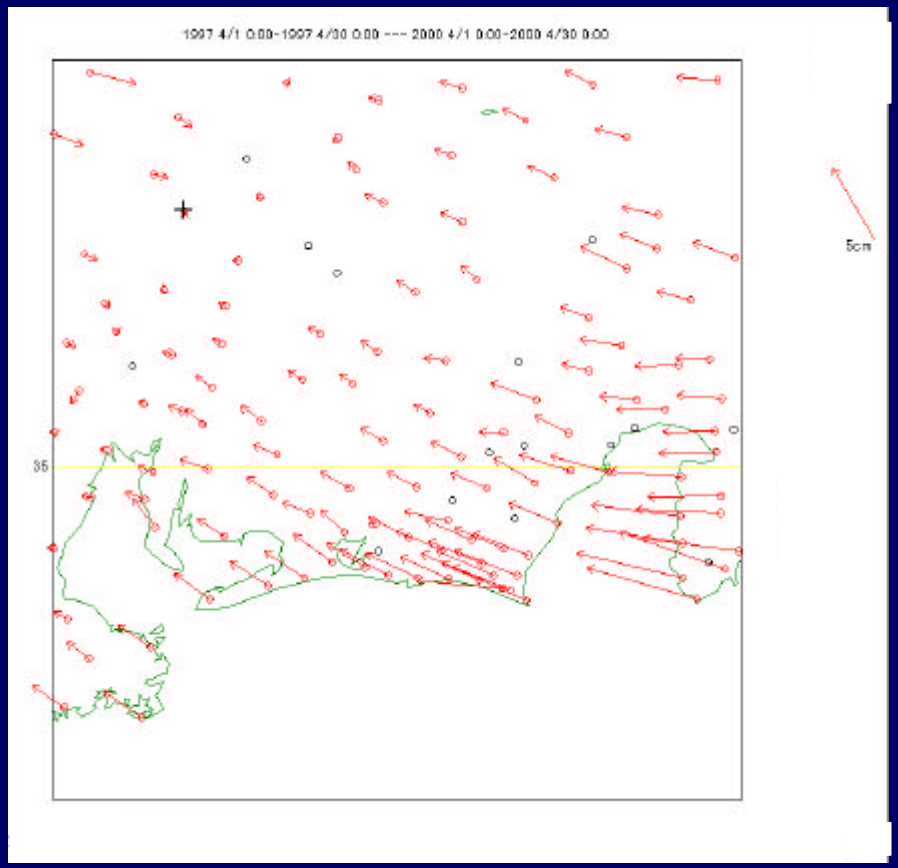
Simulation result



20 to 17 years before EQ

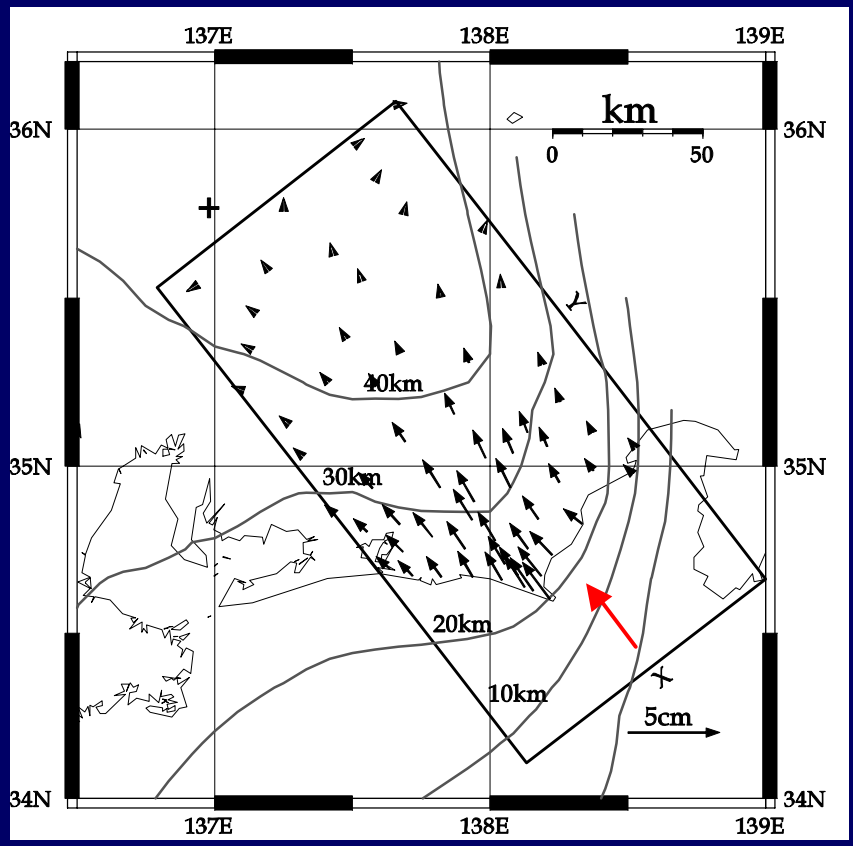
Comparison between GPS observation and simulation result for the horizontal displacement

GPS observation



April 1997 – April 2000

Simulation result



20 to 17 years before EQ

Summary

- A highly shear-stressed ring-shaped zone is formed 50 years before the earthquake around a strongly coupled region.
- Preslip gives rise to level change of the order of 1mm and volumetric strain change of 10^{-8} to 10^{-7}.
- Subsidence at Hamaoka relative to Kakegawa turns to uplift several years before the earthquake.
- The results of the simulation agree well with crustal deformation observed by leveling and GPS.