Possible Mechanisms of Coseismic Changes in Groundwater Level – Recent Examples –

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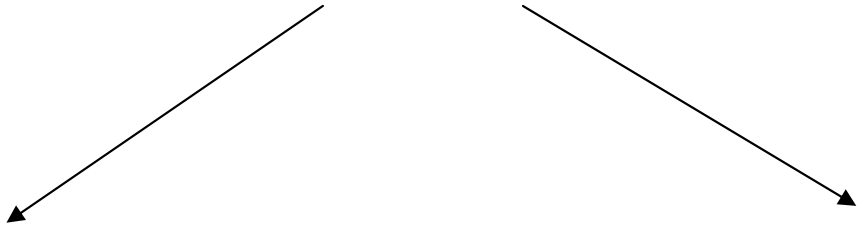
Possible mechanisms of changes in groundwater level

- Volumetric strain change
- Ground shaking
- Shaking-induced dilatancy
- Mobilization of bubble gas
- Fracture of impermeable fault
- Unknown reason?

Coseismic changes in groundwater level



Volumetric strain change?

Ground shaking?

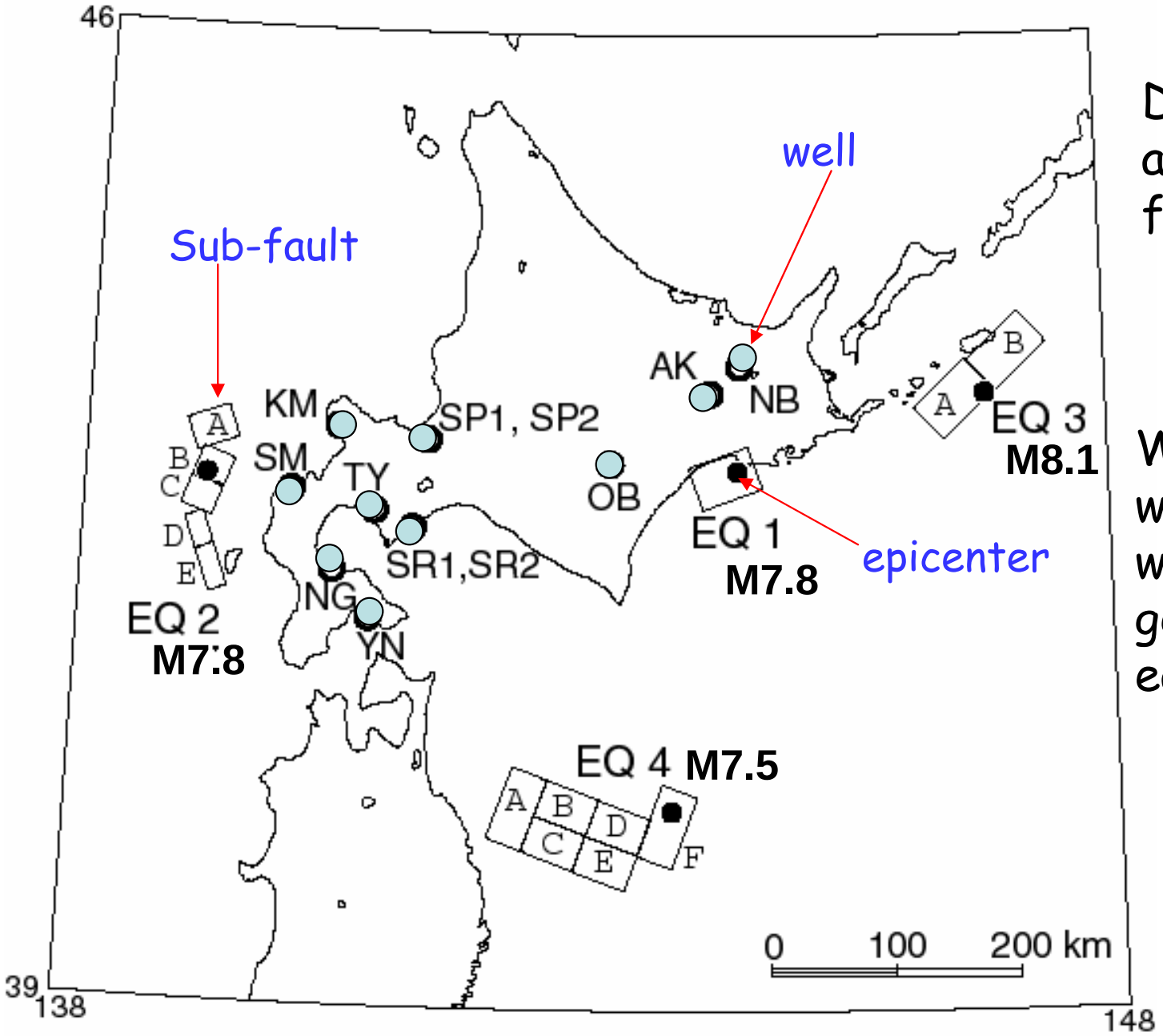
e.g.
Groundwater level change: strain changes
Stream flow: ground shaking
(Montgomery and Manga, Science, 2003)

What is the cause of coseismic groundwater level changes? Strain? Others?

- Observation of several coiseismic changes are needed at the same well.
- Comparison of well's sensitivities to strain is needed:

  tidal response v.s. coseismic water level change

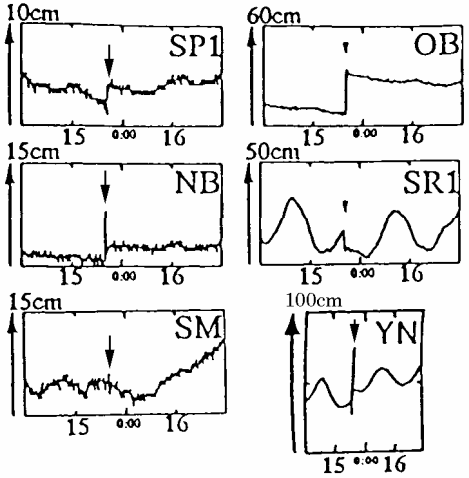
Example #1: Hokkaido. M7-8 earthquakes in 1993-1994



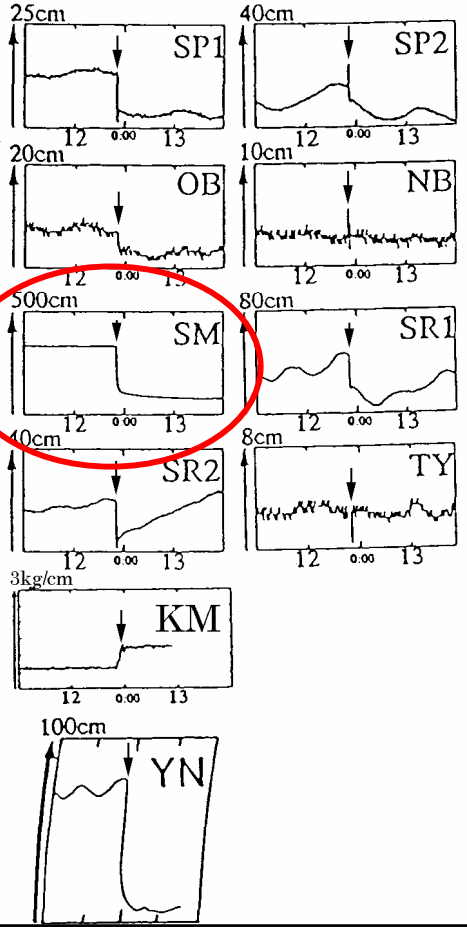
Different strain fields are anticipated by the four earthquakes.

We compare coseismic water-level changes with strain fields generated by the four earthquakes.

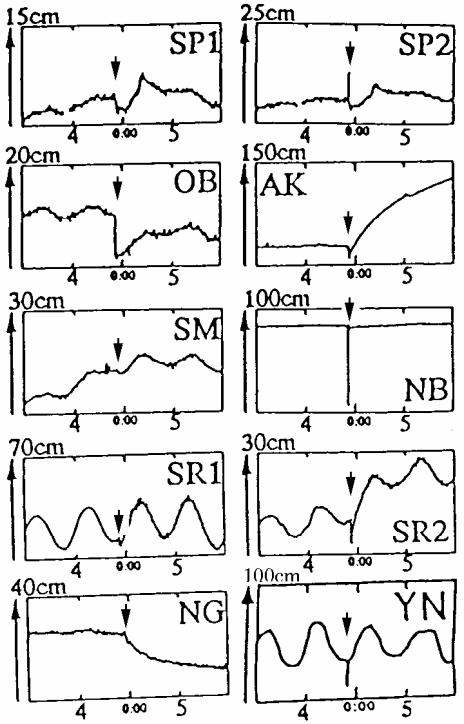
EQ 1



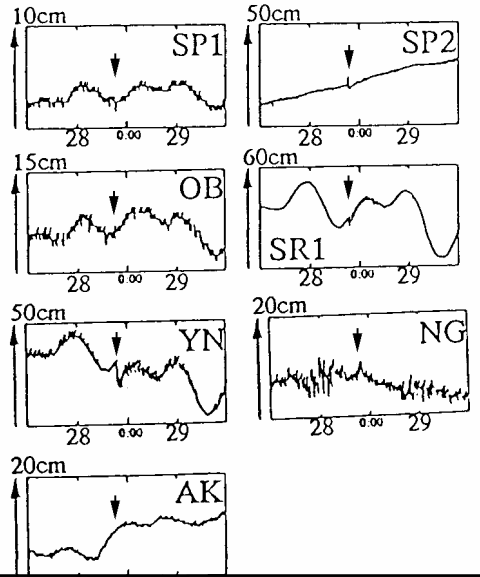
EQ 2



EQ 3



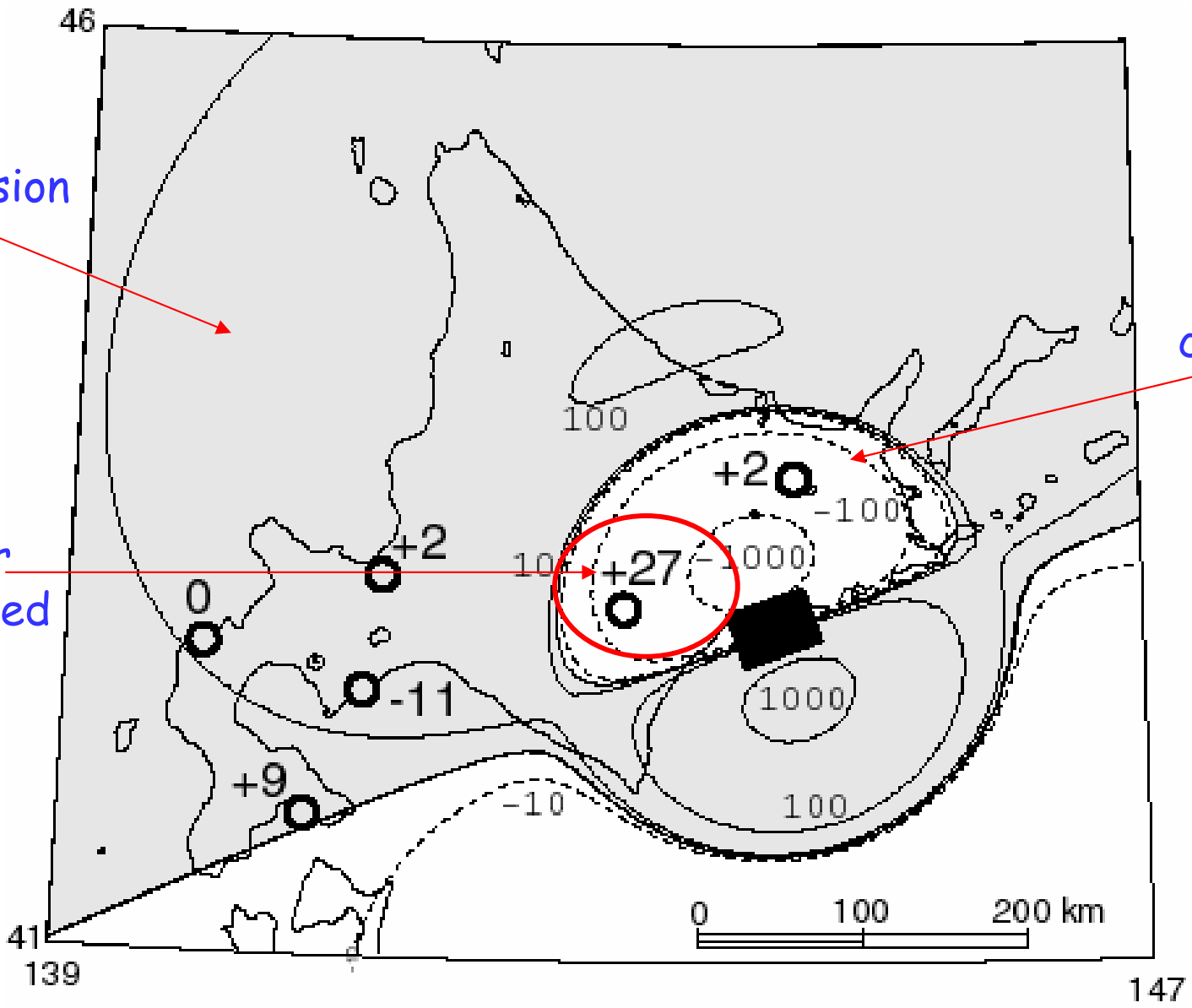
EQ 4



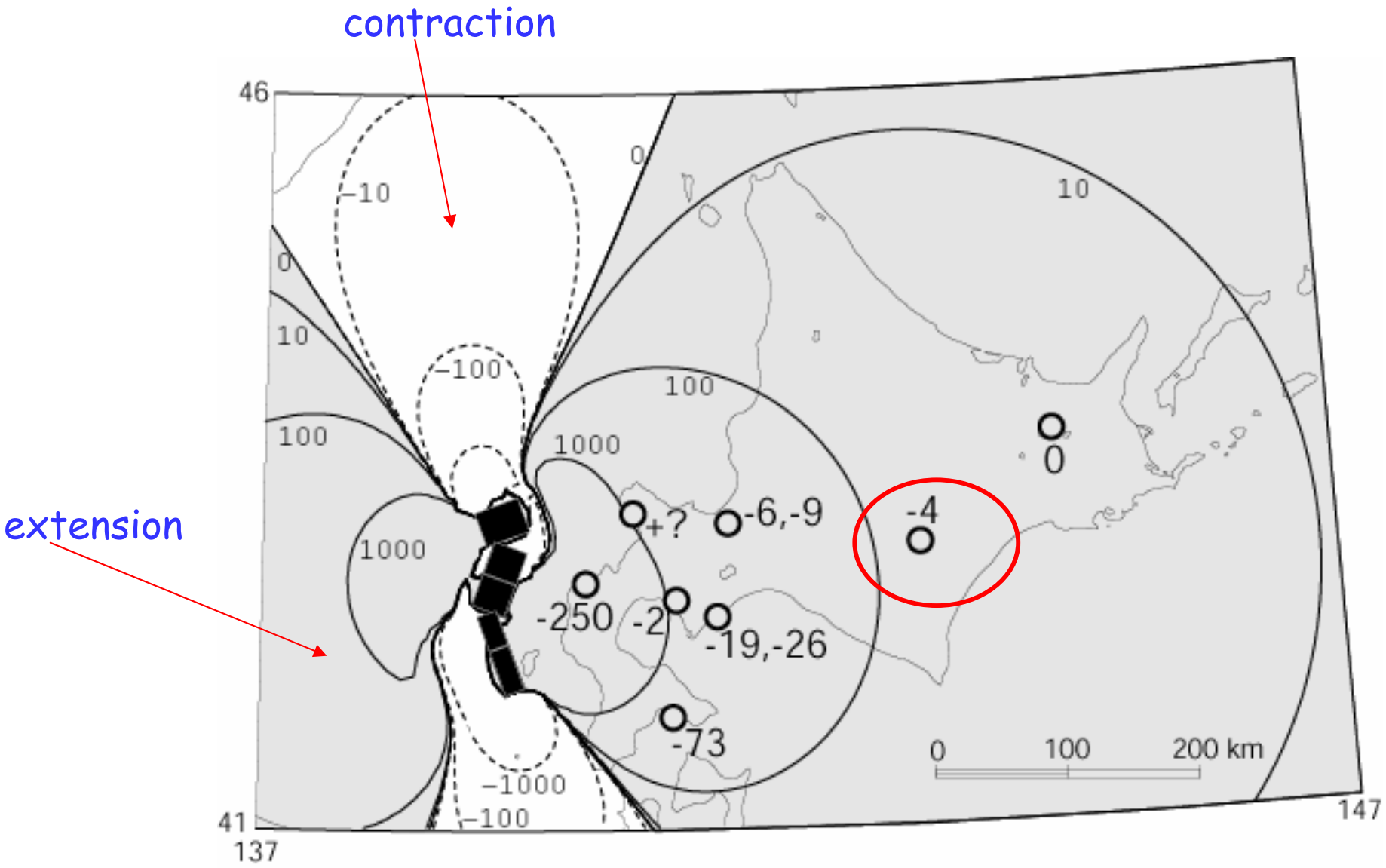
Coseismic water-level changes in response to the EQs

Maximum: 2.5 m decrease in SM

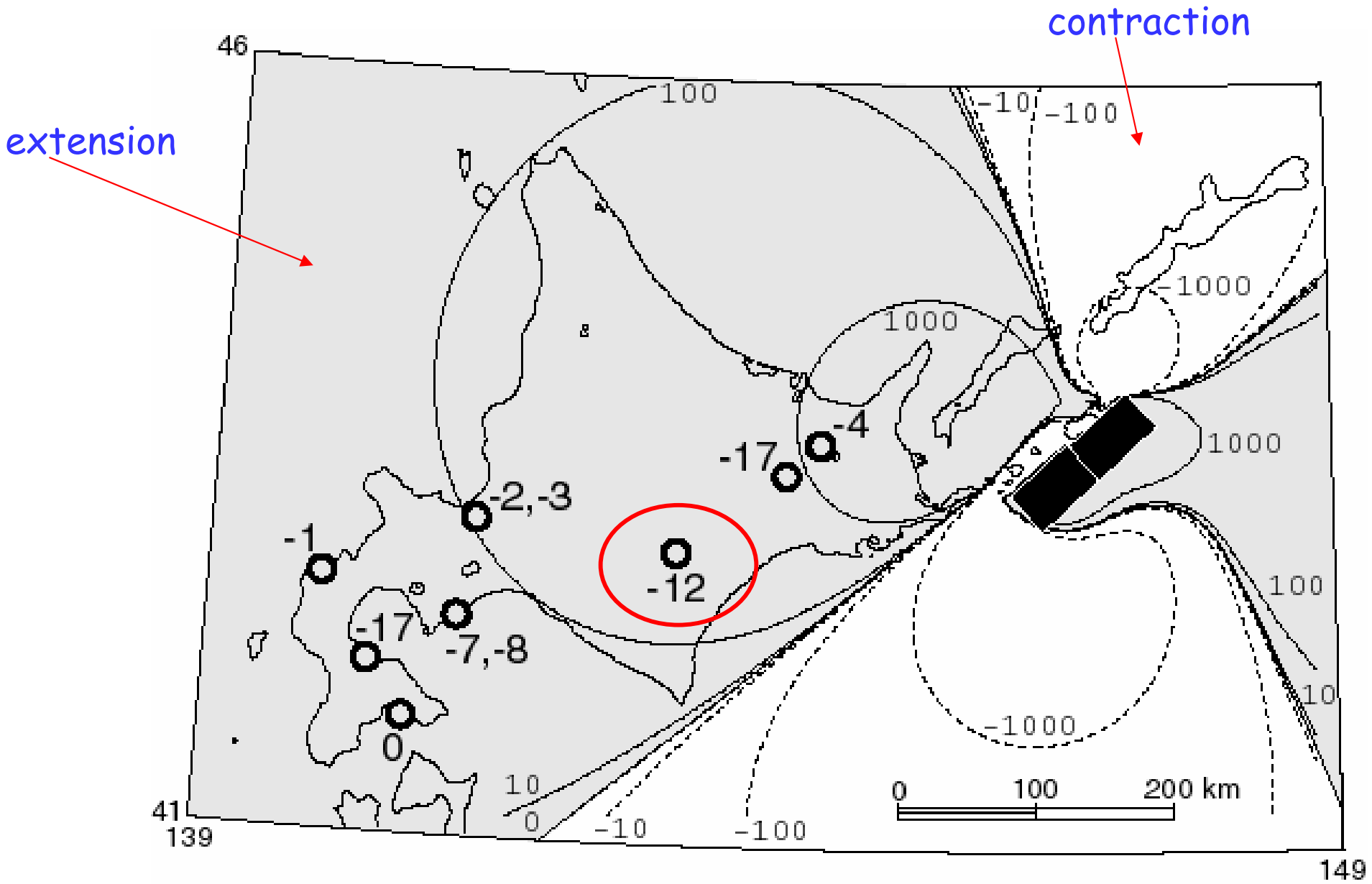
Strain field due to EQ1 and coseismic groundwater-level change



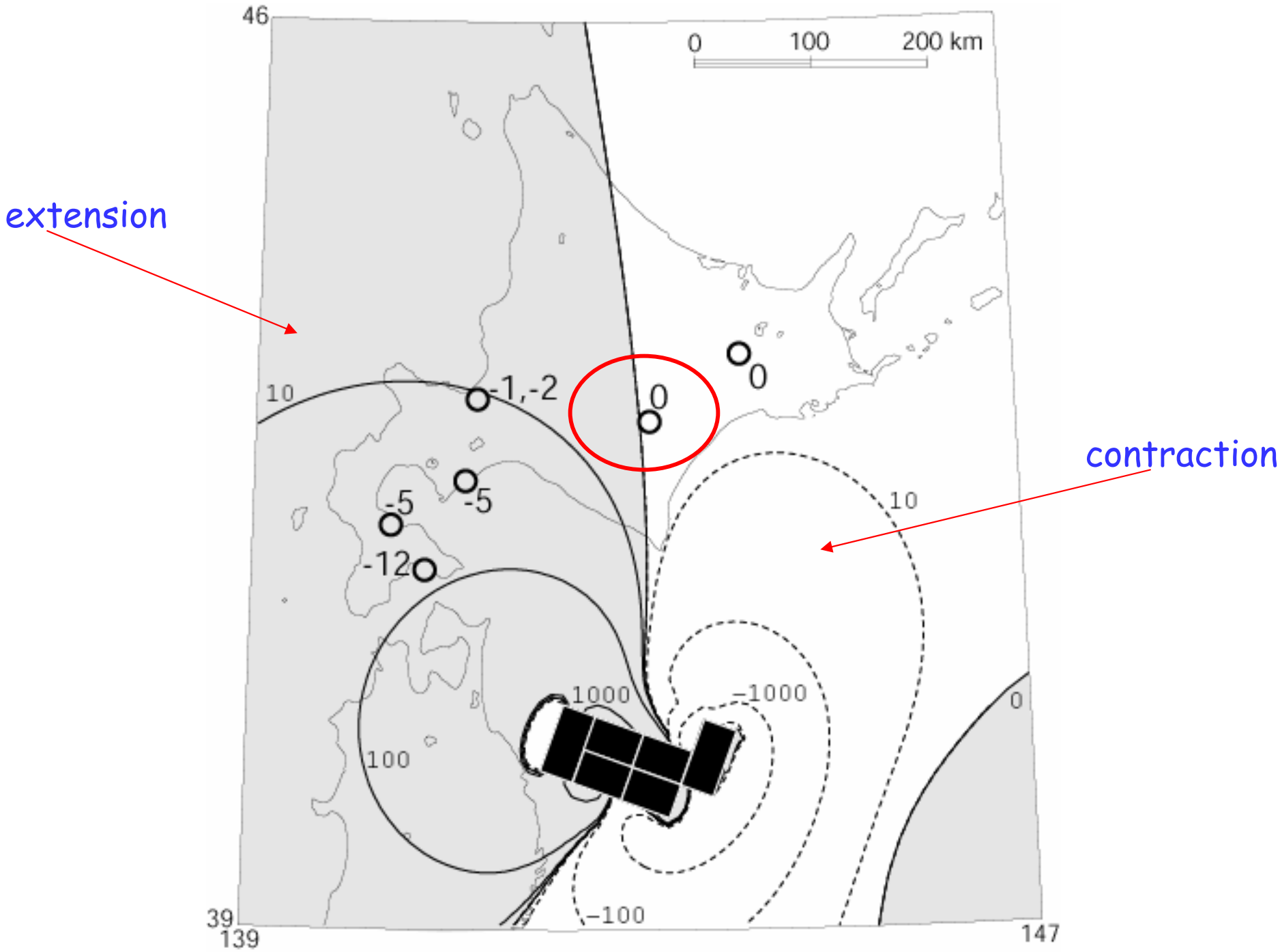
Strain field due to EQ2 and coseismic groundwater-level change

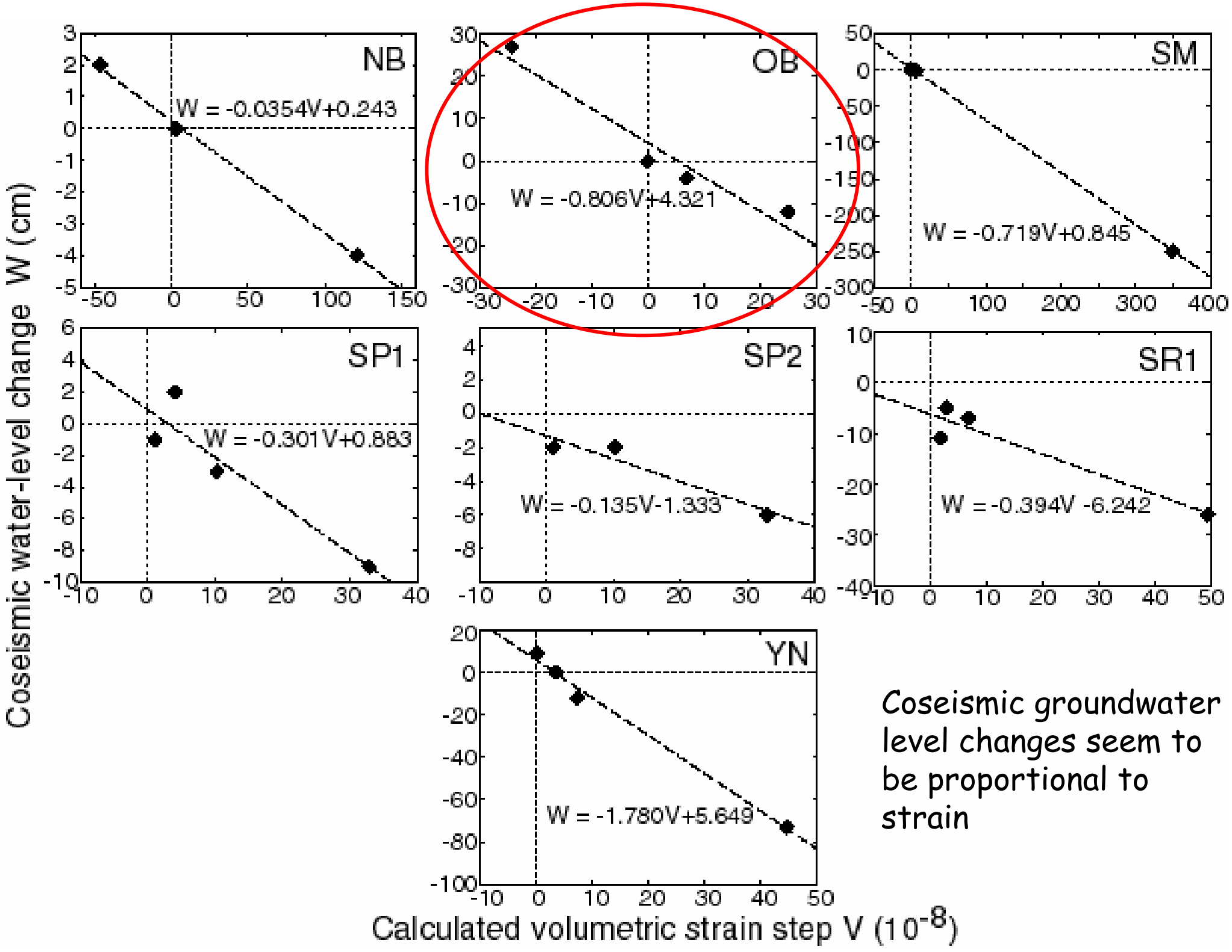


Strain field due to EQ3 and coseismic groundwater-level change



Strain field due to EQ4 and coseismic groundwater-level change

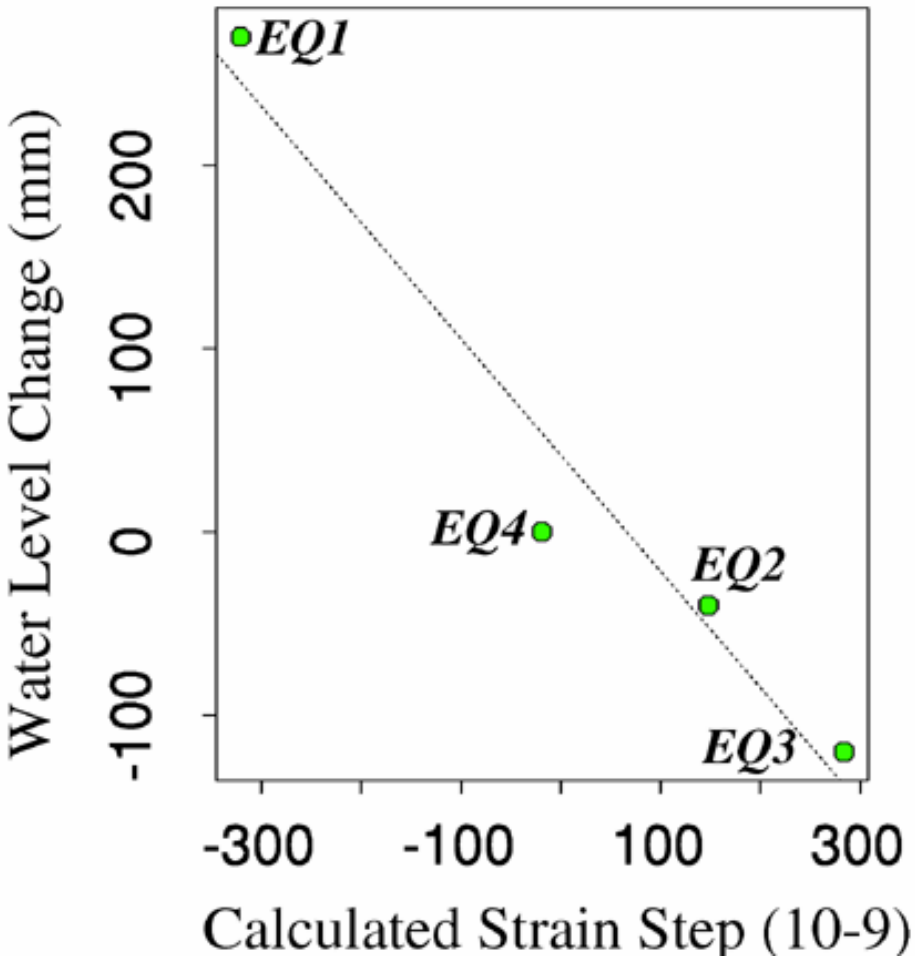




Coseismic groundwater level changes seem to be proportional to strain

OBIHIRO

Depth : 1328m
Screened Depth : 950 ~ 1060m
Permeability : 10-3 ~ 10-4 cm/sec



Detailed analysis

Tidal response: -5.5 mm / 10^{-8}

Coseimic response

1. Strain only

   - 8.1 mm / 10^{-8}

2. Strain + Ground motion

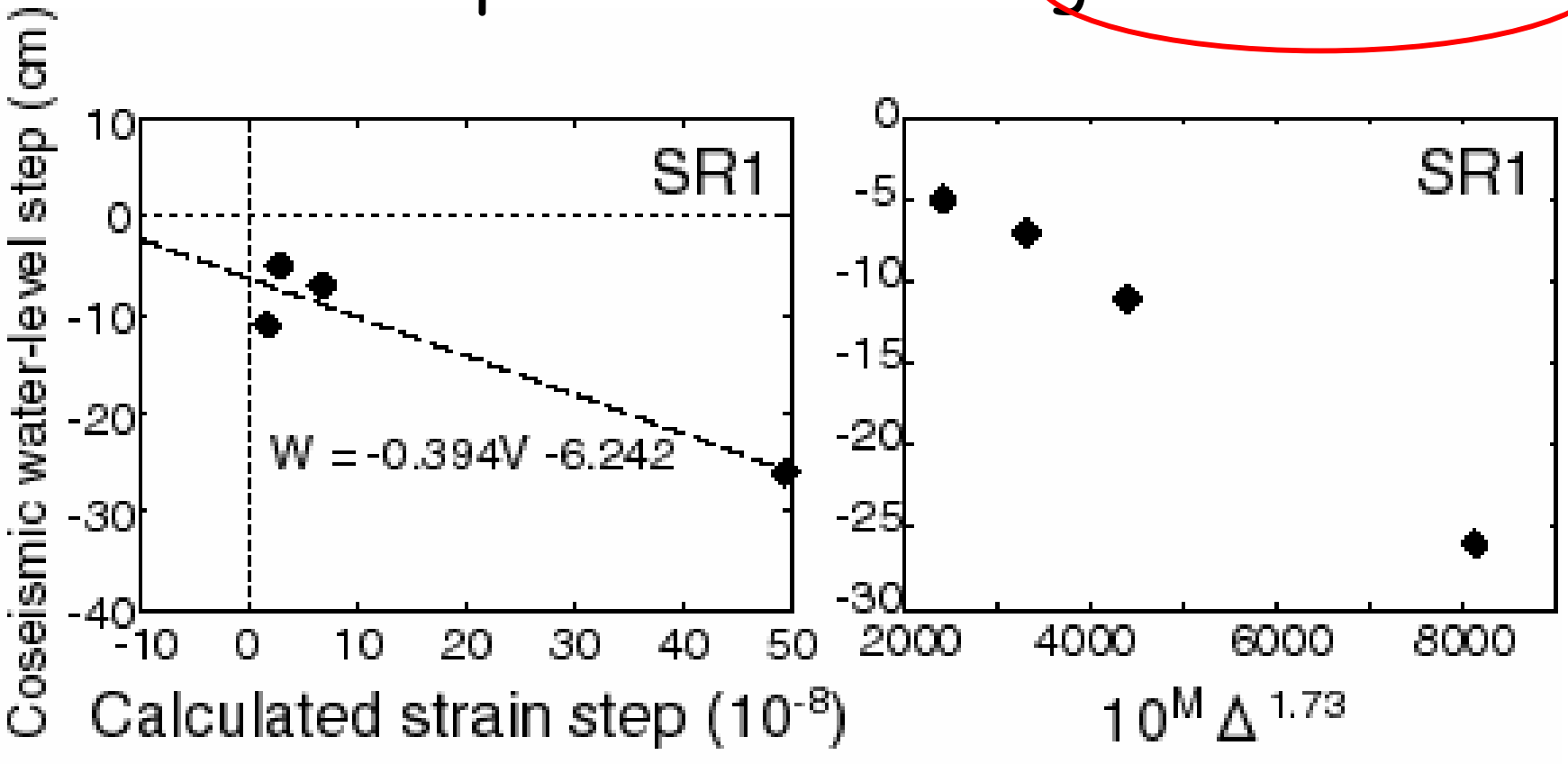
   - 6.3 mm / 10^{-8}

   Statistically optimal and close to tidal response

Large contribution of strain

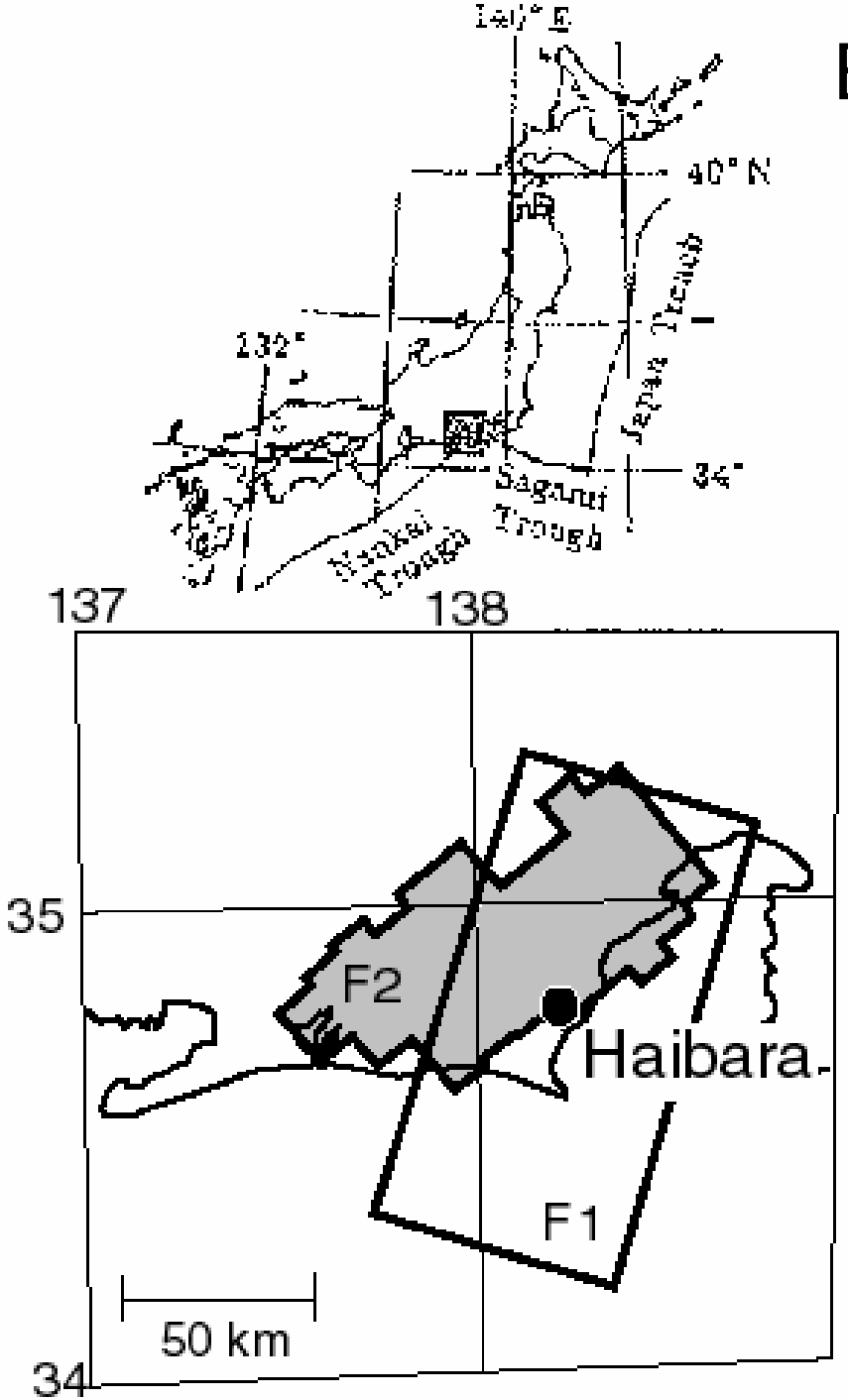
Some contribution of ground motion

Groundwater- level change in SR1:
response to strain? ground motion?



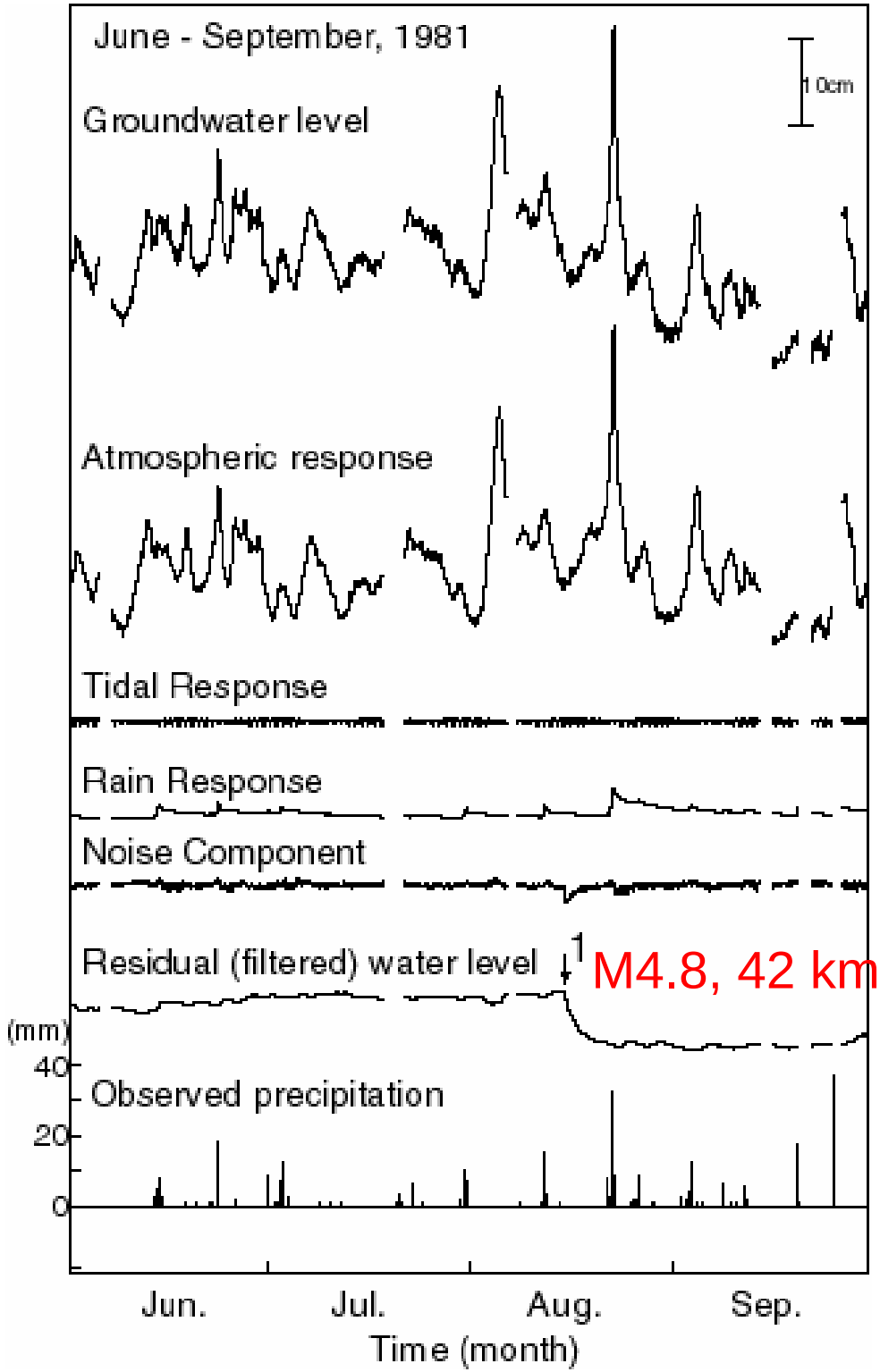
SR1 well: contribution of ground motion seems to be larger than that of strain step.

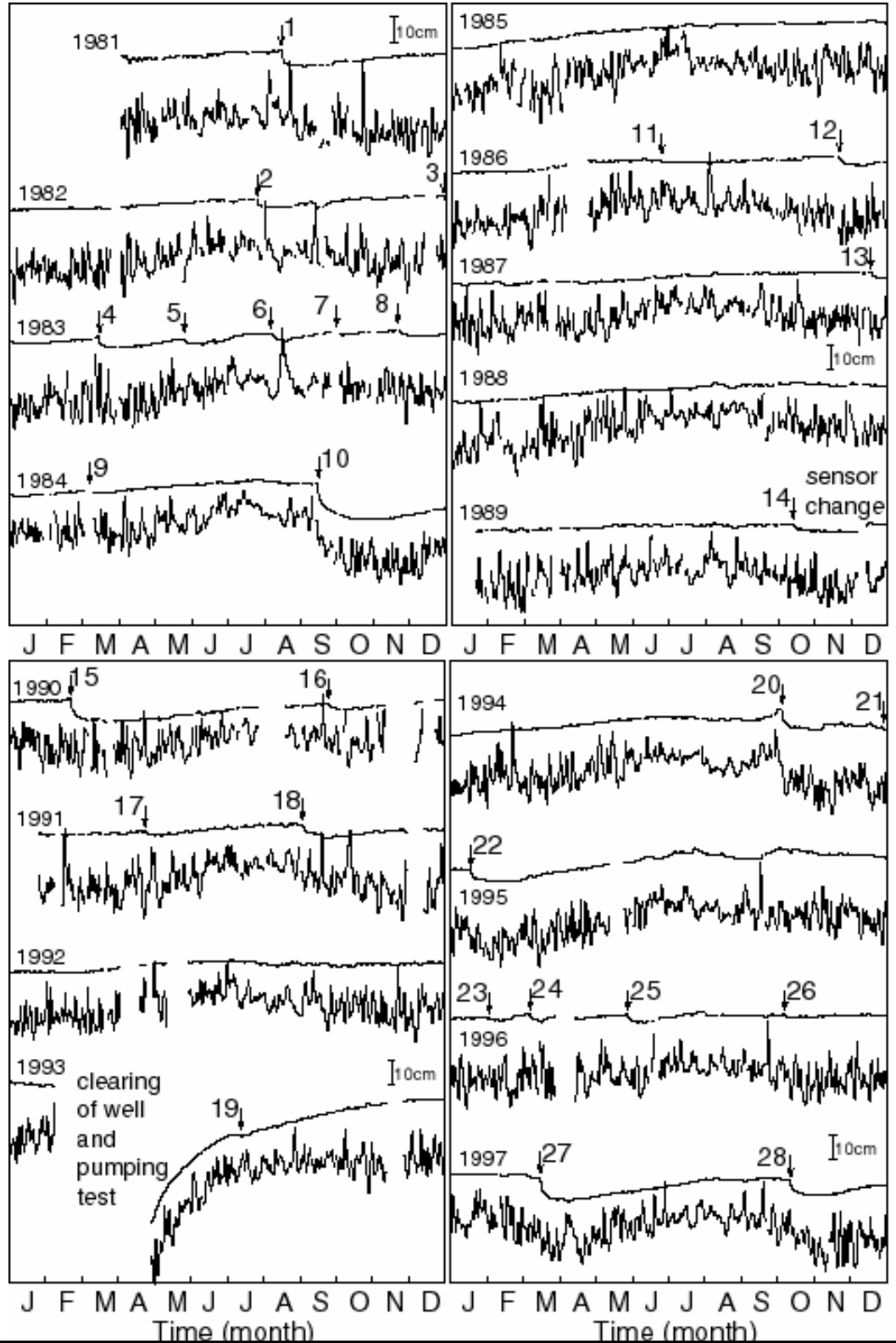
Optimal model: $W = -0.161\ V - 0.0220\ A$



Example #2:
Haibara well, central Japan

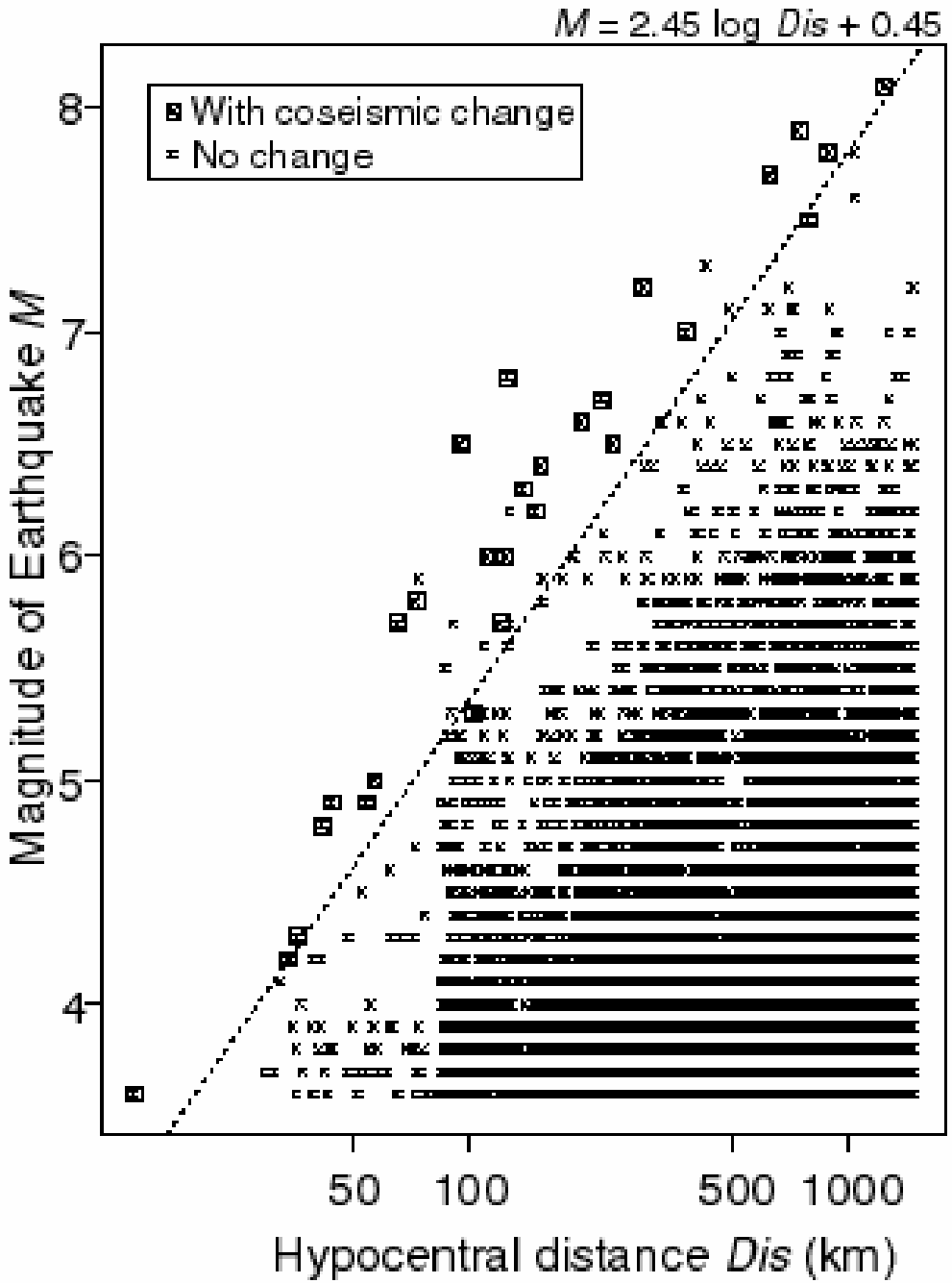
Just above anticipated rupture zone of the future Tokai earthquake


June - September, 1981
10cm
Groundwater level
Atmospheric response
Tidal Response
Rain Response
Noise Component
Residual (filtered) water level
1
M4.8, 42 km
(mm)
40
Observed precipitation
20
0
Jun.
Jul.
Aug.
Sep.
Time (month)



Haibara well

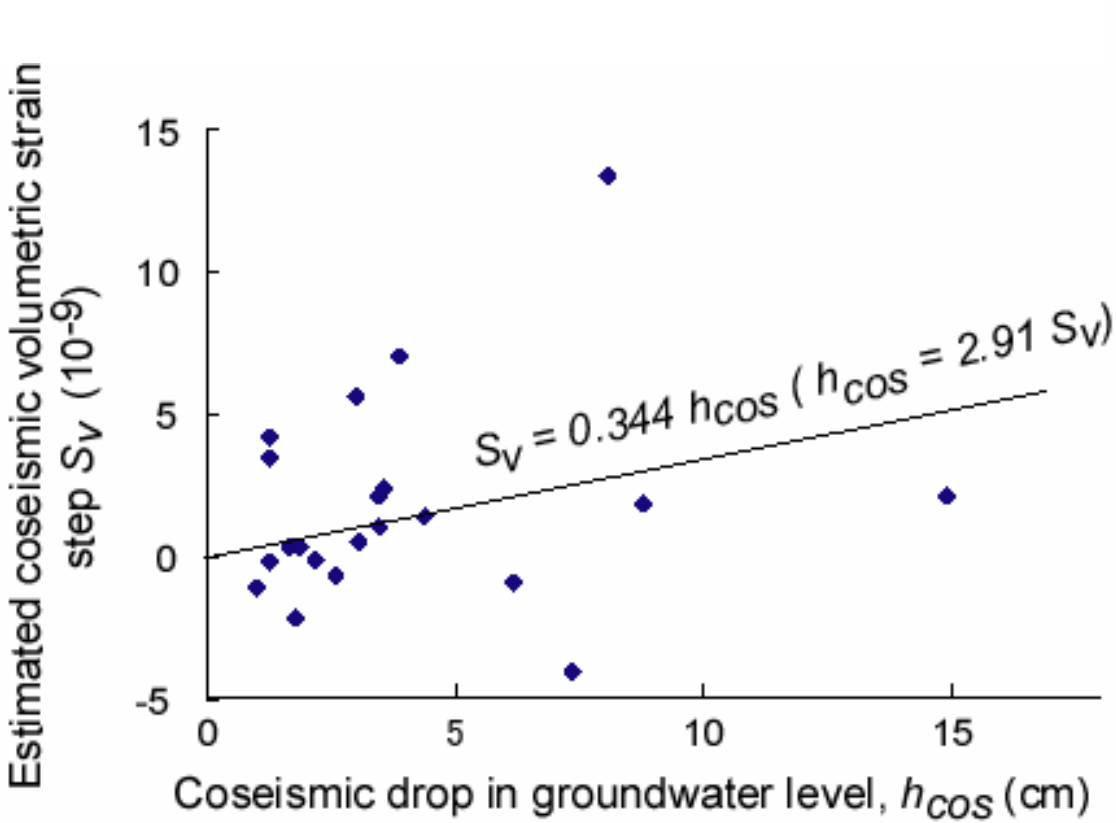
- 28 coseismic changes in 1981-1997.
- All coseismic changes are decreases in water-level.
- Estimated strain changes are very small ($< 10^{-8}$).

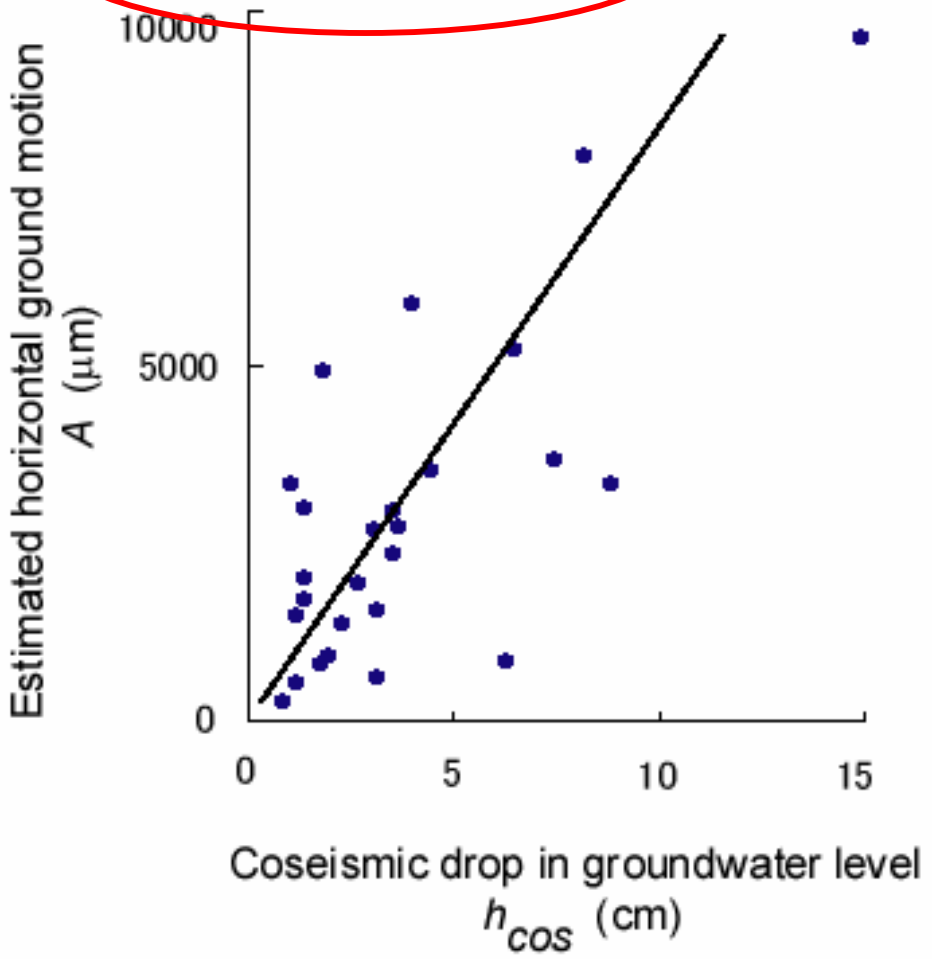


Magnitude vs Hypocentral distance

- All earthquakes M >3.5 and Dis < 1500 km between 1981 and 1997 are plotted.
- 26 of the 28 EQs satisfy M > 2.45 log Dis + 0.45.

Groundwater- level change: response to strain? ground motion?



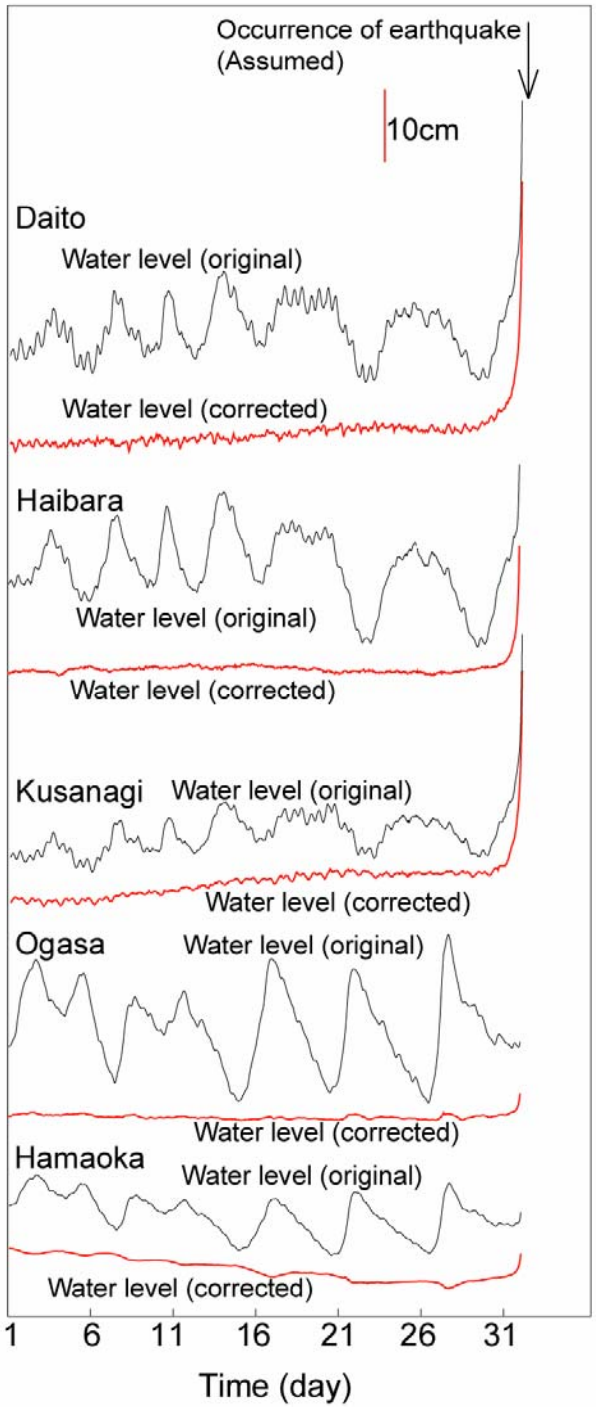


- Strain sensitivity: tidal response 2.2 mm /10^{-8}, coseismic change: 291 mm/10^{-8}. One hundred times larger than tidal response!
- Correlation coefficients: strain vs water level: 0.19, ground motion vs water level: 0.74

Conclusions

- Mechanisms of coseismic changes in groundwater level are expected by coseismic strain step and/or ground shaking.
- Contribution of strain step and ground shaking to coseismic change in water level seems to be different in each well.
- Several coseismic changes in water level and/or comparison with tidal response are needed to know the detailed mechanism.

Importance of strain sensitivity to detect preseismic sliding



Response of groundwater level to strain is very important to evaluate groundwater level change in response to preseismic sliding.

We assumed M6 preseismic sliding started three days before the mainshock at 10 km depth under each well.

We can observe anomalous groundwater level data associated with the preseismic sliding 1 - 45 hours before the mainshock.