A Joint Analysis of Groundwater Changes and Crustal Deformation Related to Earthquake Swarms off the East Coast of Izu Peninsula, Japan

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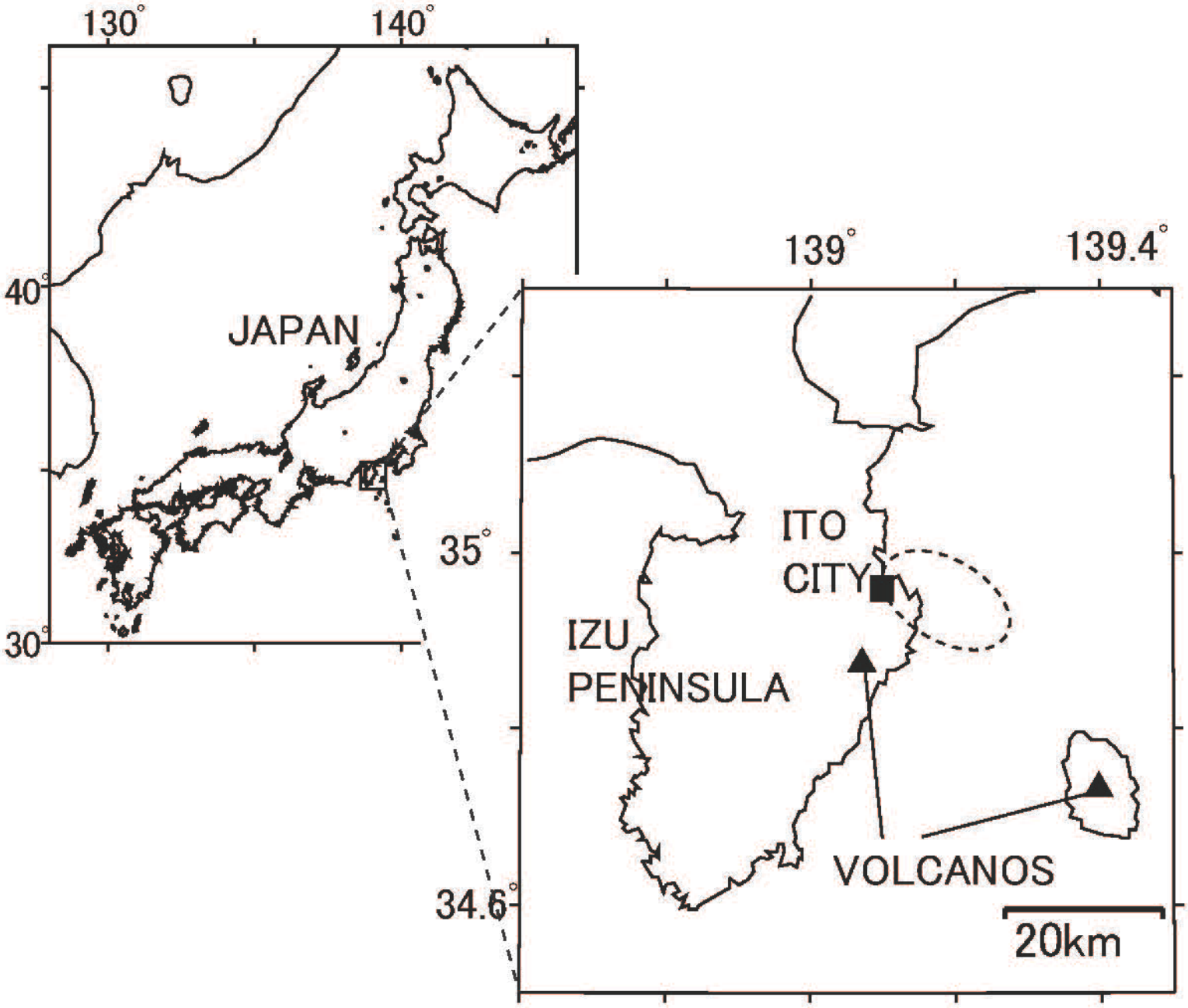
OUTLINE

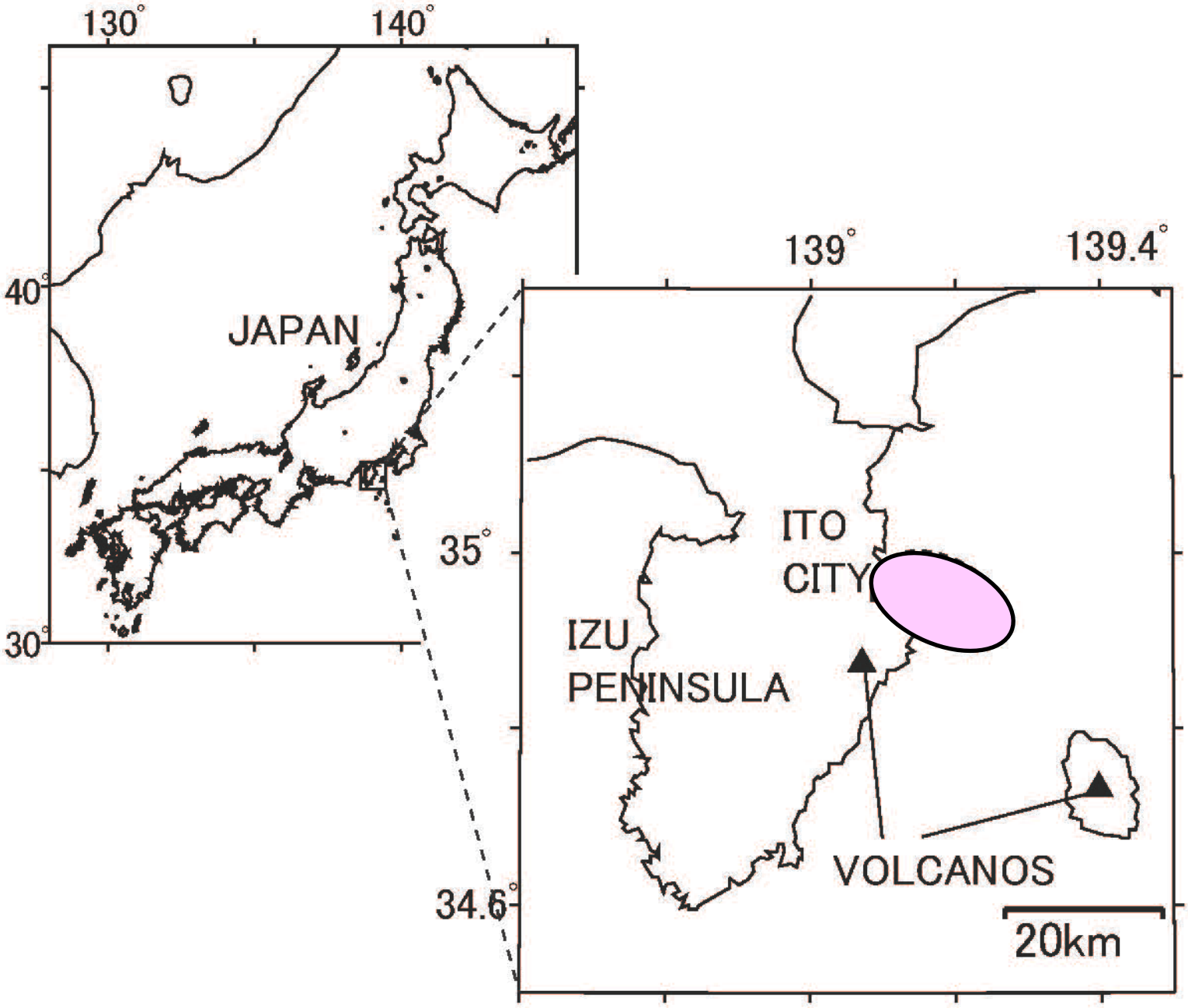
1・Earthquake Swarms off the East Coast of Izu Peninsula, Japan. They Repeatedly Caused Crustal Deformation and Groundwater Changes.

2・Different Fault Models for Explaining Individual Crustal Deformation and Groundwater Level Change for the Earthquake Swarms.

3. A Joint Analysis of Groundwater Changes and Crustal Deformation for a Comprehensive Model .

4. Examination of the Comprehensive Model.


130°
140°
40°
JAPAN
30°
139°
139.4°
35°
ITO
CITY
IZU
PENINSULA
VOLCANOS
34.6°
20km


130°
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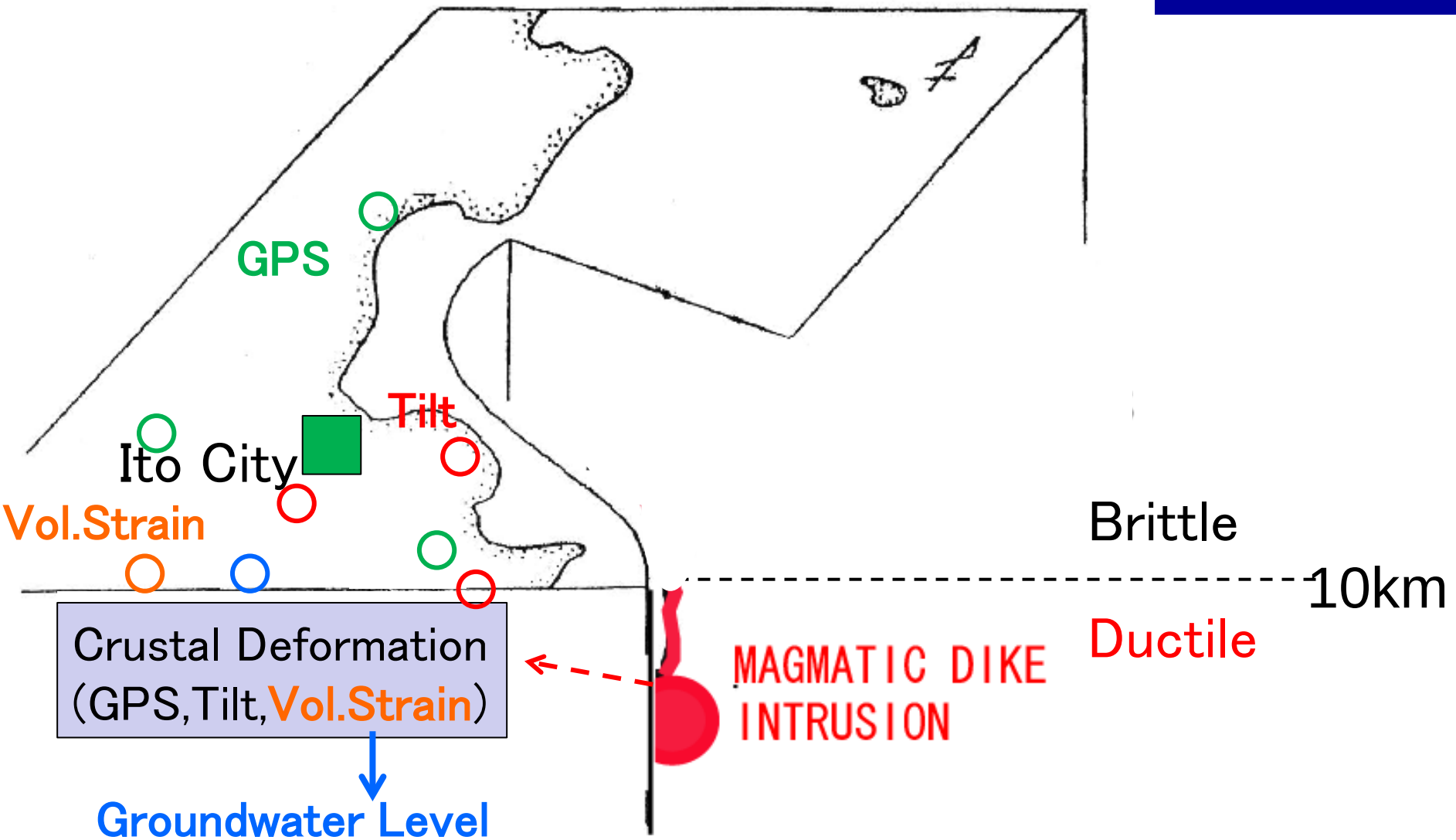
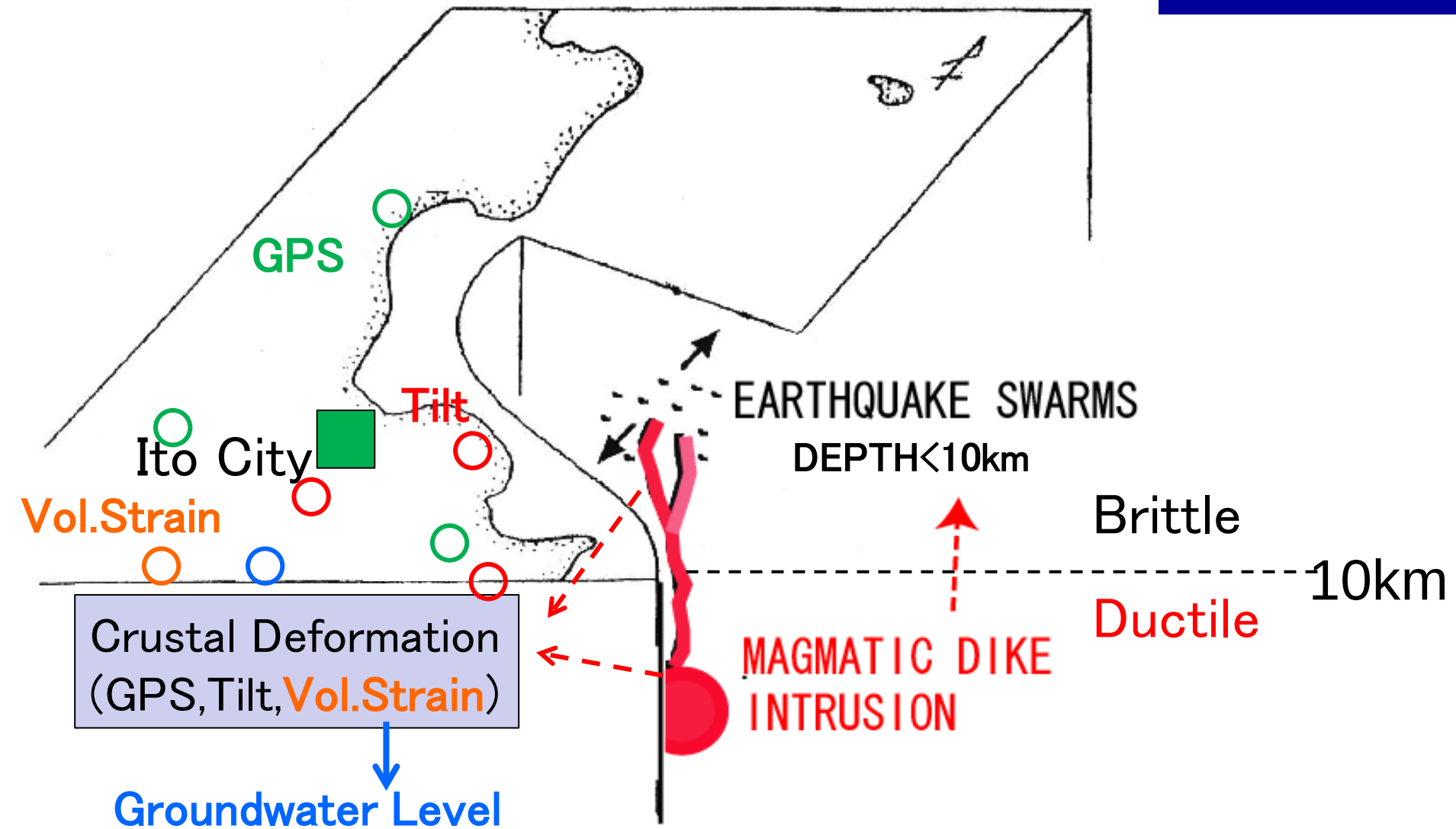
ITO
CITY
IZU
PENINSULA
VOLCANOS
20km

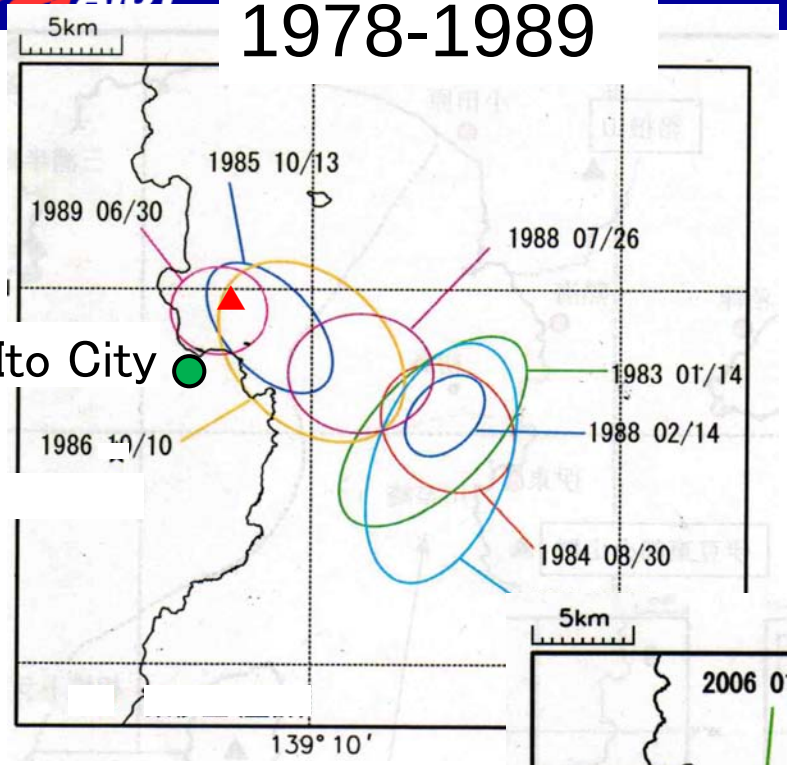

GPS
Tilt
Ito City
Vol.Strain
Brittle
10km
Ductile
Crustal Deformation
(GPS,Tilt,Vol.Strain)
MAGMATIC DIKE
INTRUSION
Groundwater Level

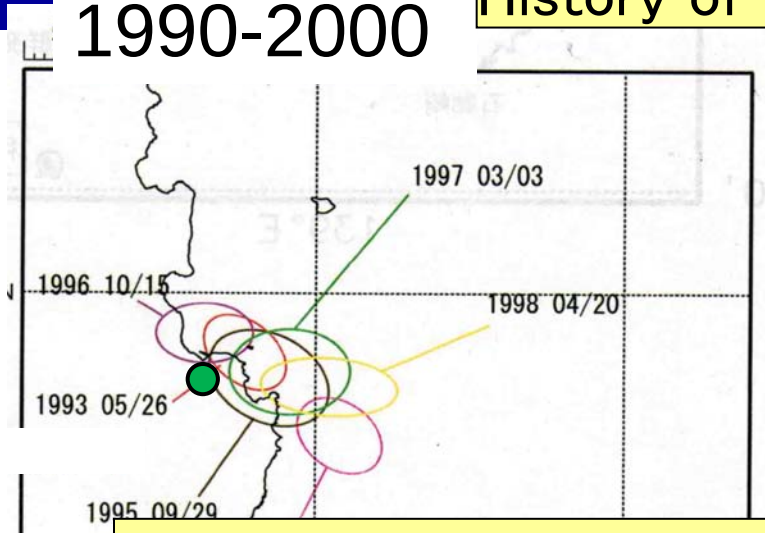


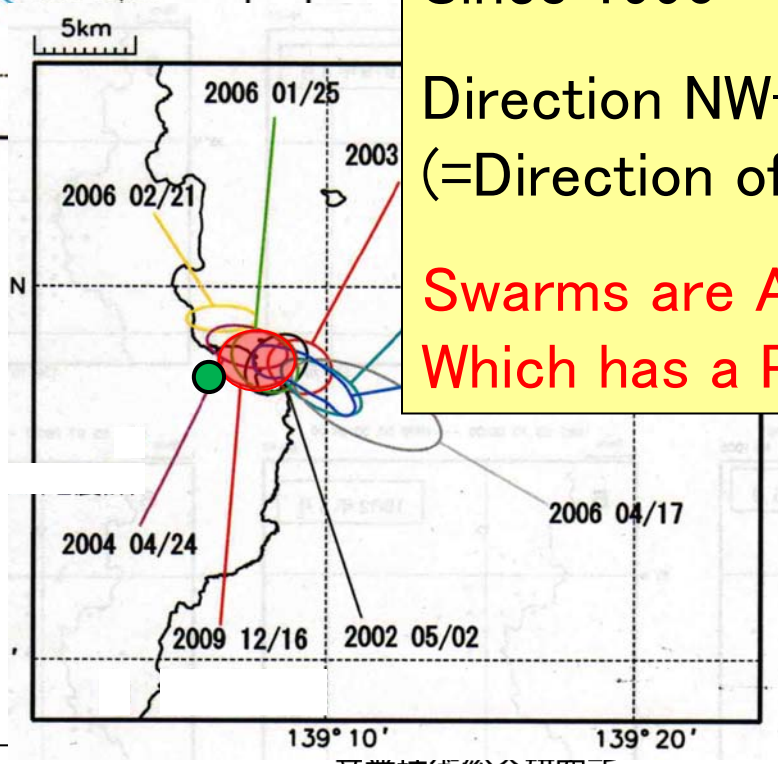
Preseismic Change in GWL & Crustal Deformation.

Prompt Grasp of the Depth of the Magma Head is More Important.

History of the Swarms





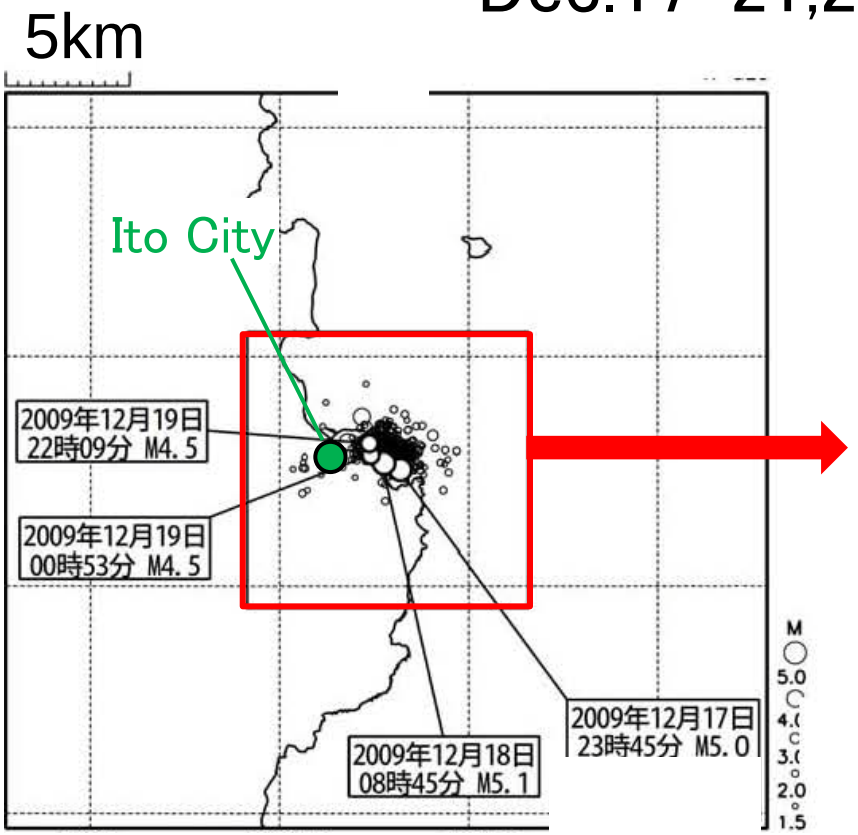


Since 1990

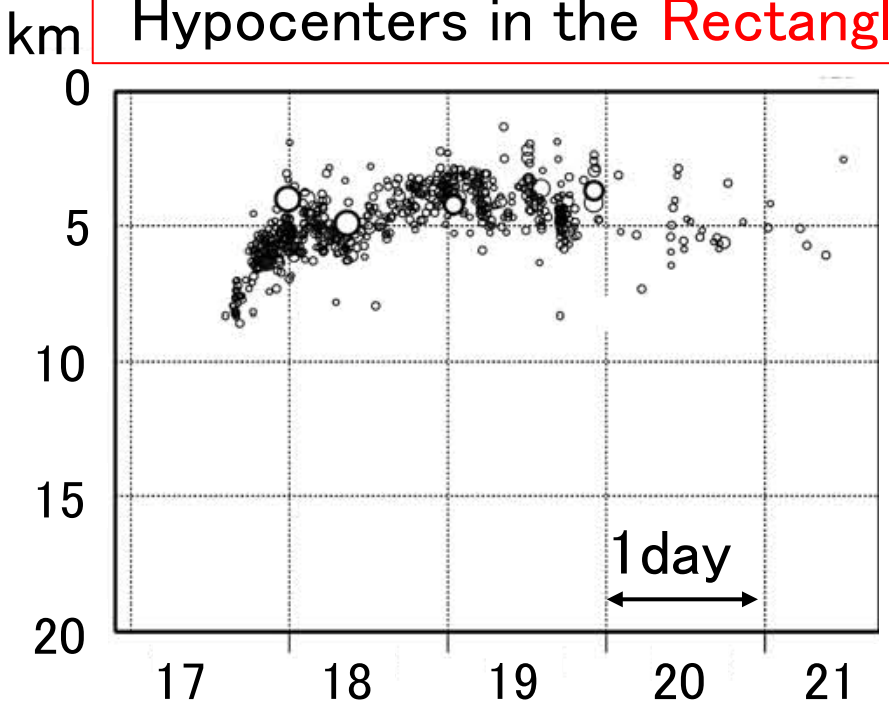
Direction NW–SE or WNW–ESE
(=Direction of PSP Motion)

Swarms are Approaching Ito City,
Which has a Population of 70,000.

Dec.17–21,2009

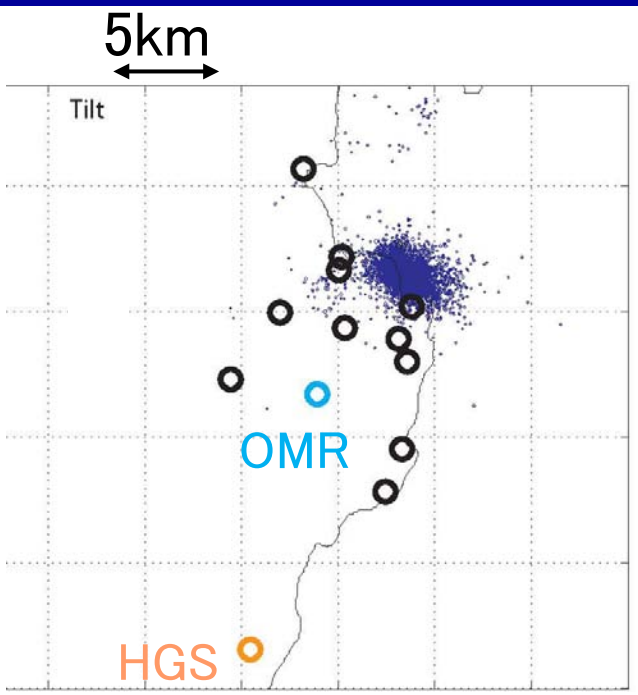


Temporal Change in Hypocenters in the Rectangle



Dec. 2009

(JMA,2010)


5km
Tilt
OMR
HGS

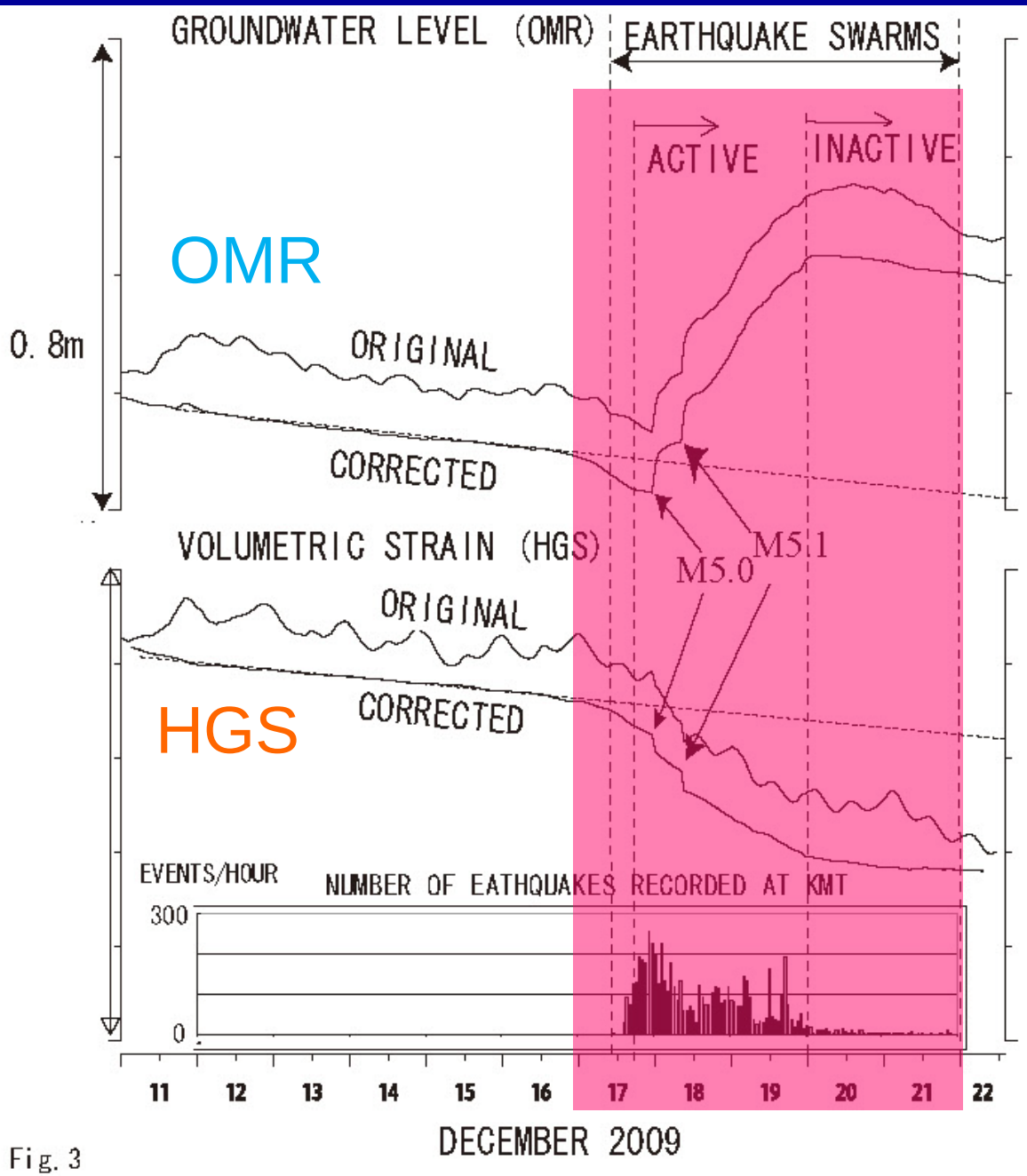
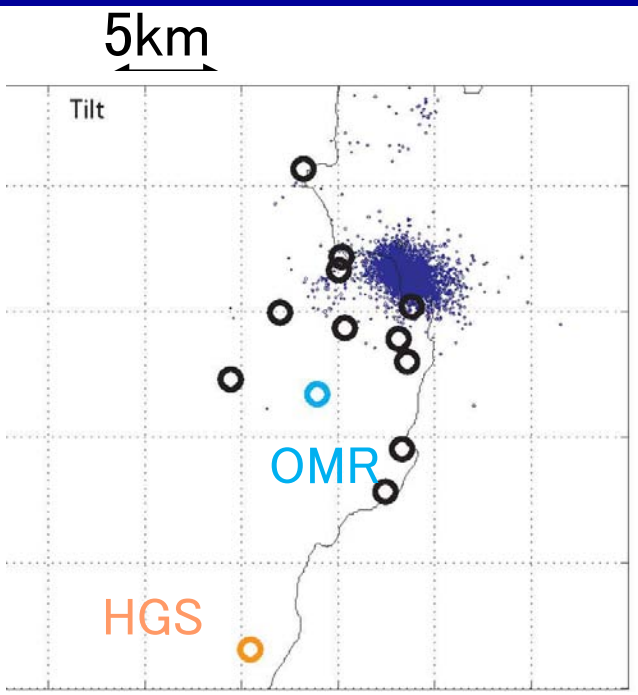
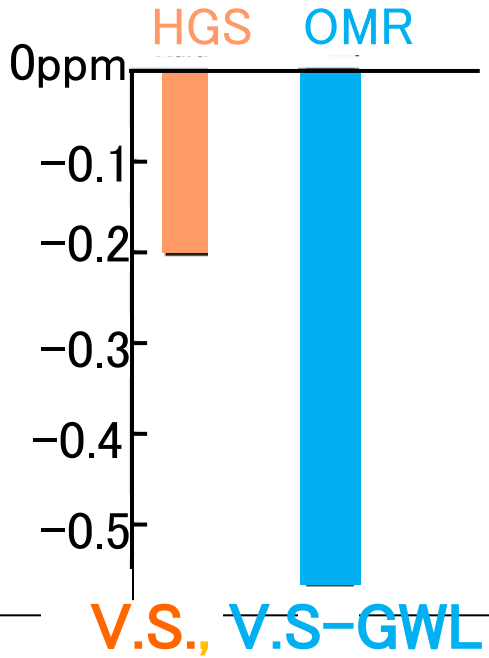
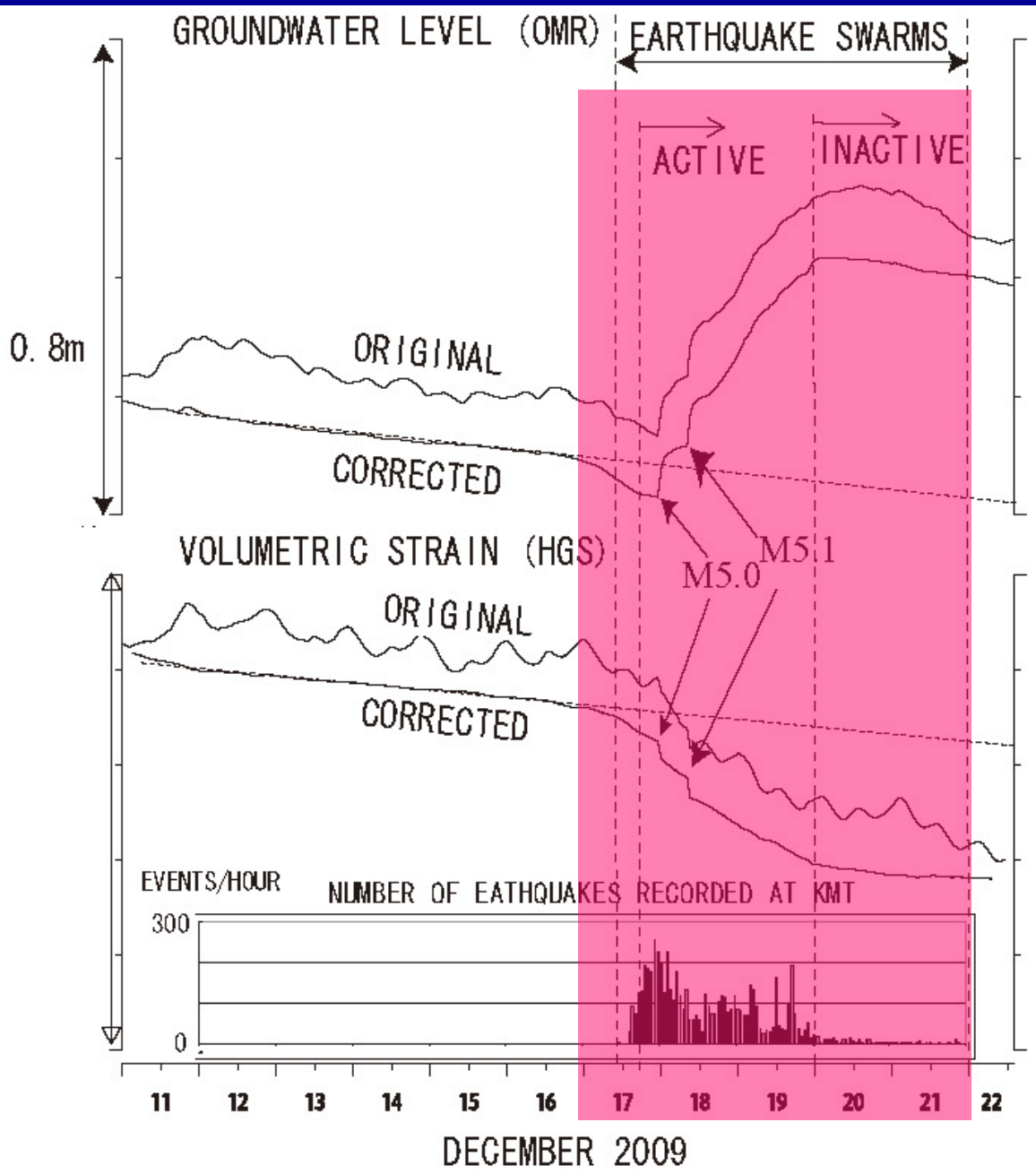

GROUNDWATER LEVEL (OMR)
EARTHQUAKE SWARMS
ACTIVE
INACTIVE
OMR
0.8m
ORIGINAL
CORRECTED
VOLUMETRIC STRAIN (HGS)
M5.0
M5.1
ORIGINAL
HGS
CORRECTED
EVENTS/HOUR
NUMBER OF EATHQUAKES RECORDED AT KMT
300
0
11
12
13
14
15
16
17
18
19
20
21
22
DECEMBER 2009

Fig. 3


5km
Tilt
OMR
HGS


HGS
OMR
0ppm
−0.1
−0.2
−0.3
−0.4
−0.5
V.S., V.S−GWL


GROUNDWATER LEVEL (OMR)
EARTHQUAKE SWARMS
ACTIVE
INACTIVE
0.8m
ORIGINAL
CORRECTED
VOLUMETRIC STRAIN (HGS)
M5.0
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EVENTS/HOUR
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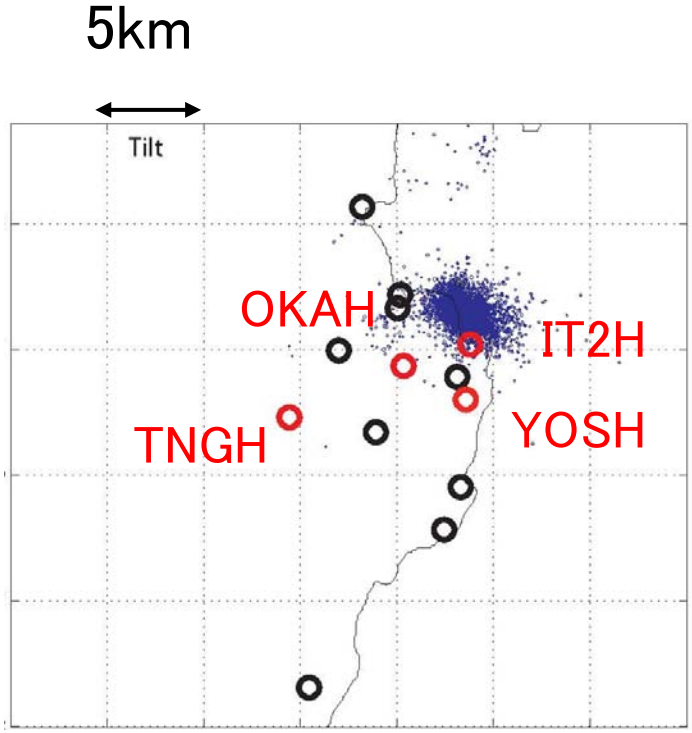
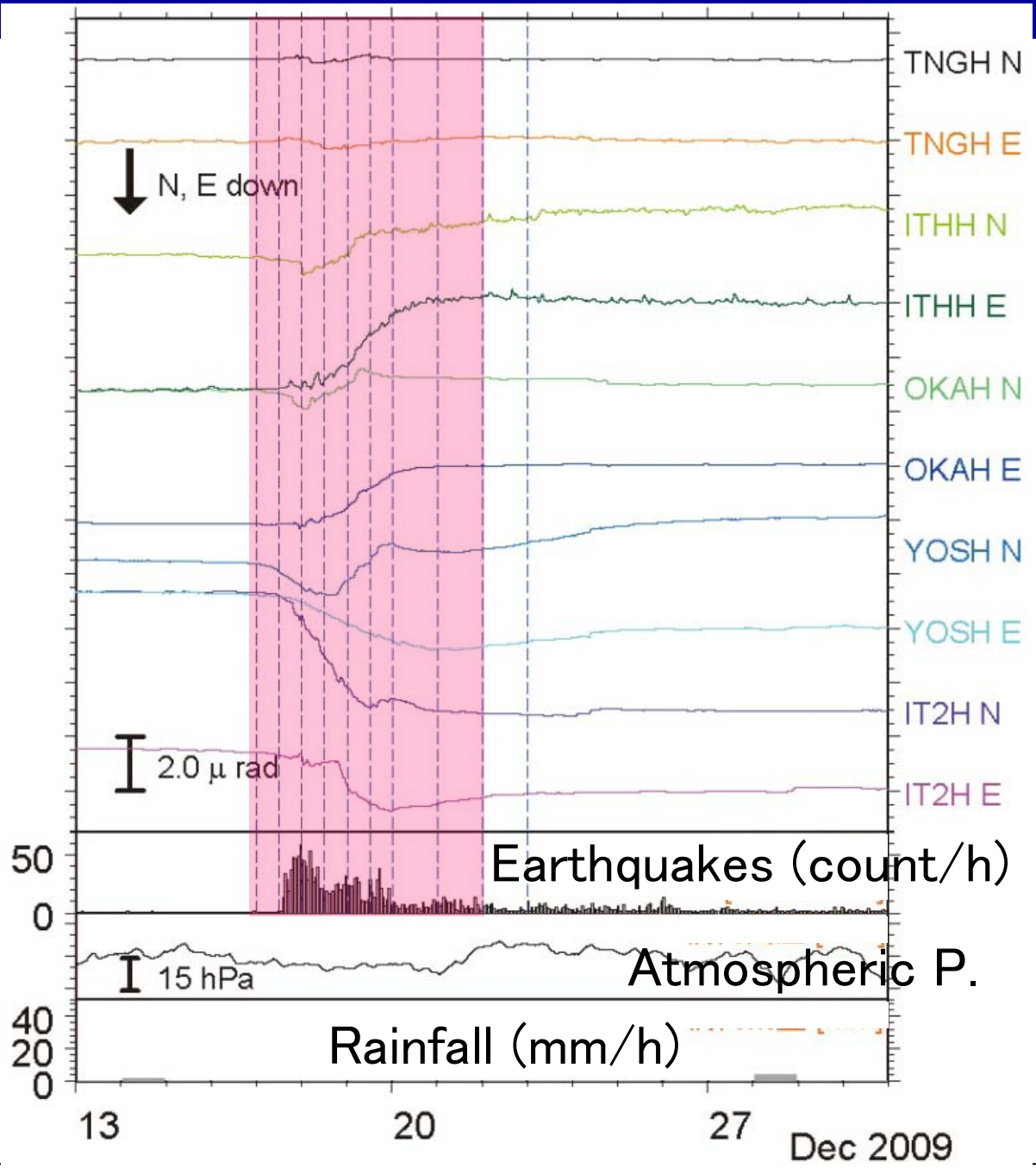
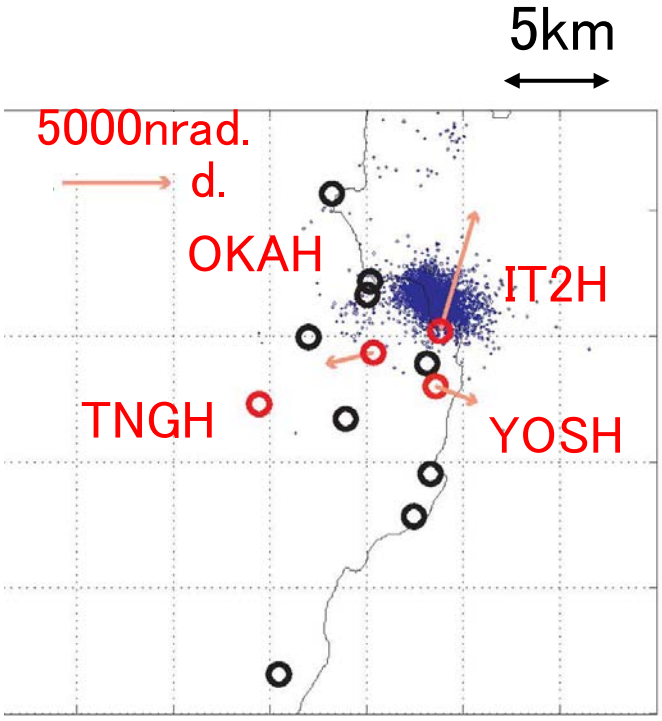
300
0
11
12
13
14
15
16
17
18
19
20
21
22
DECEMBER 2009

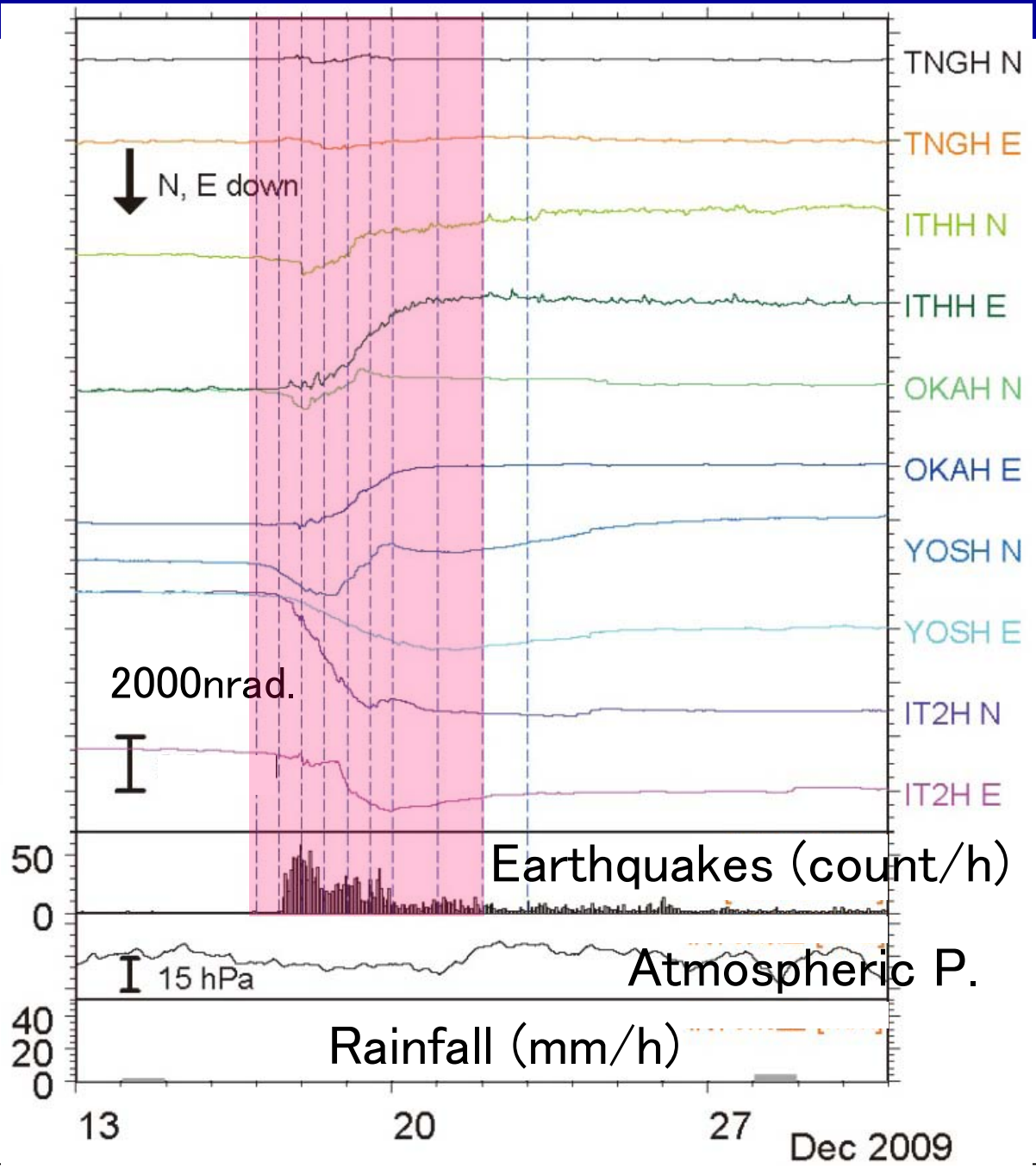


Tilt Change

(NIED,2010)







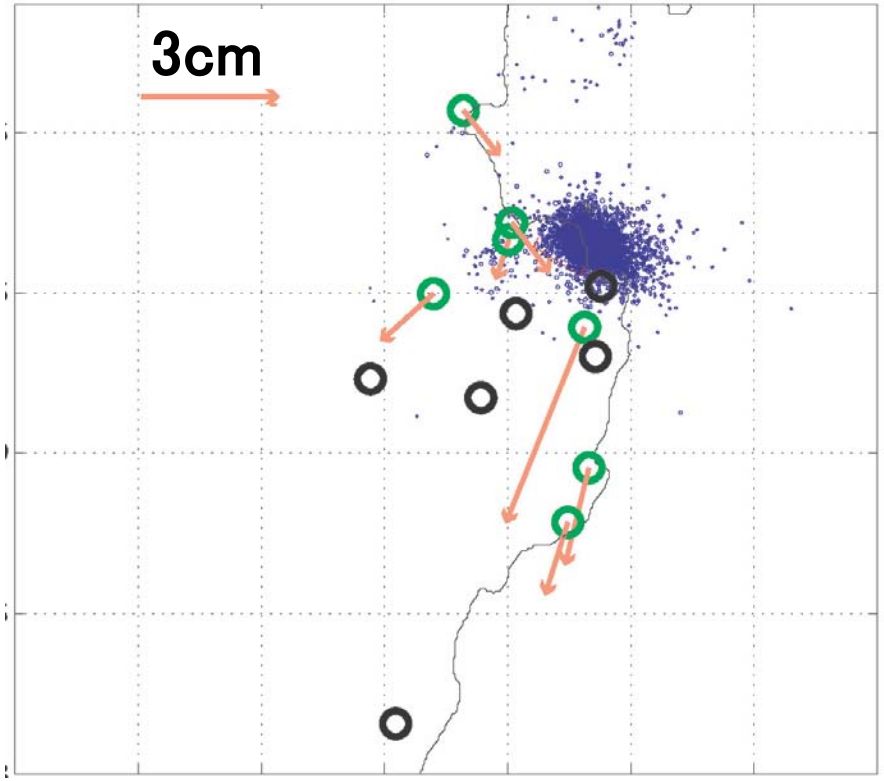
Tilt Change

(NIED,2010)

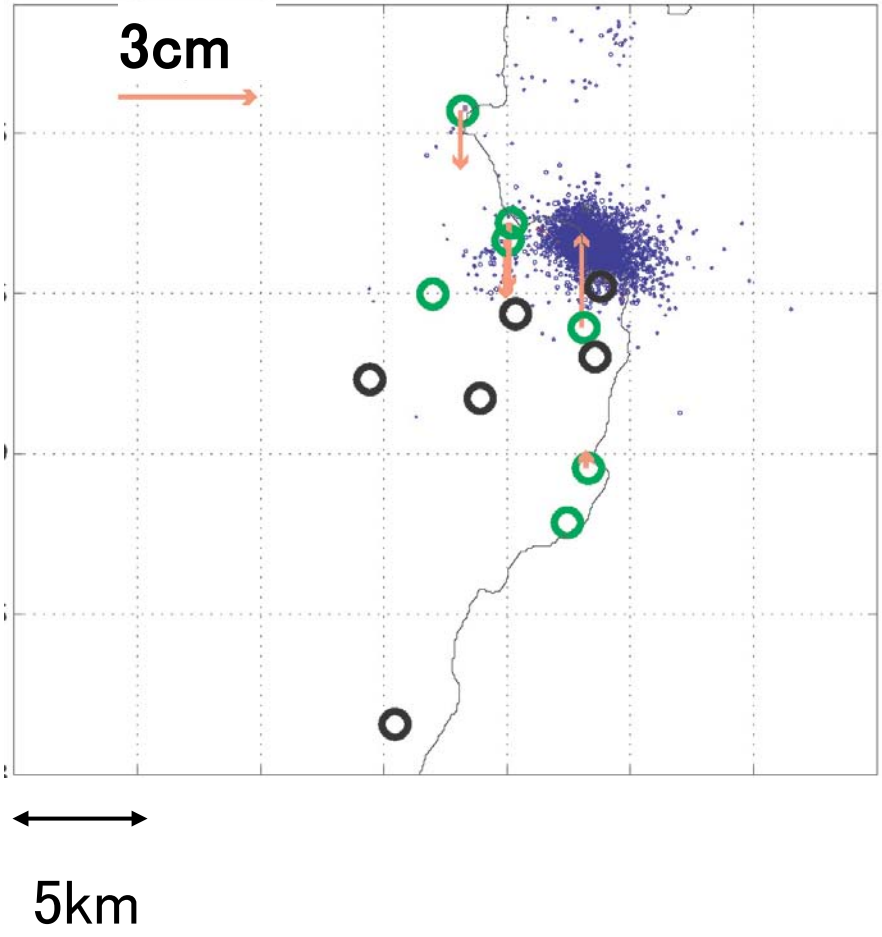
GPS (7 Stations)

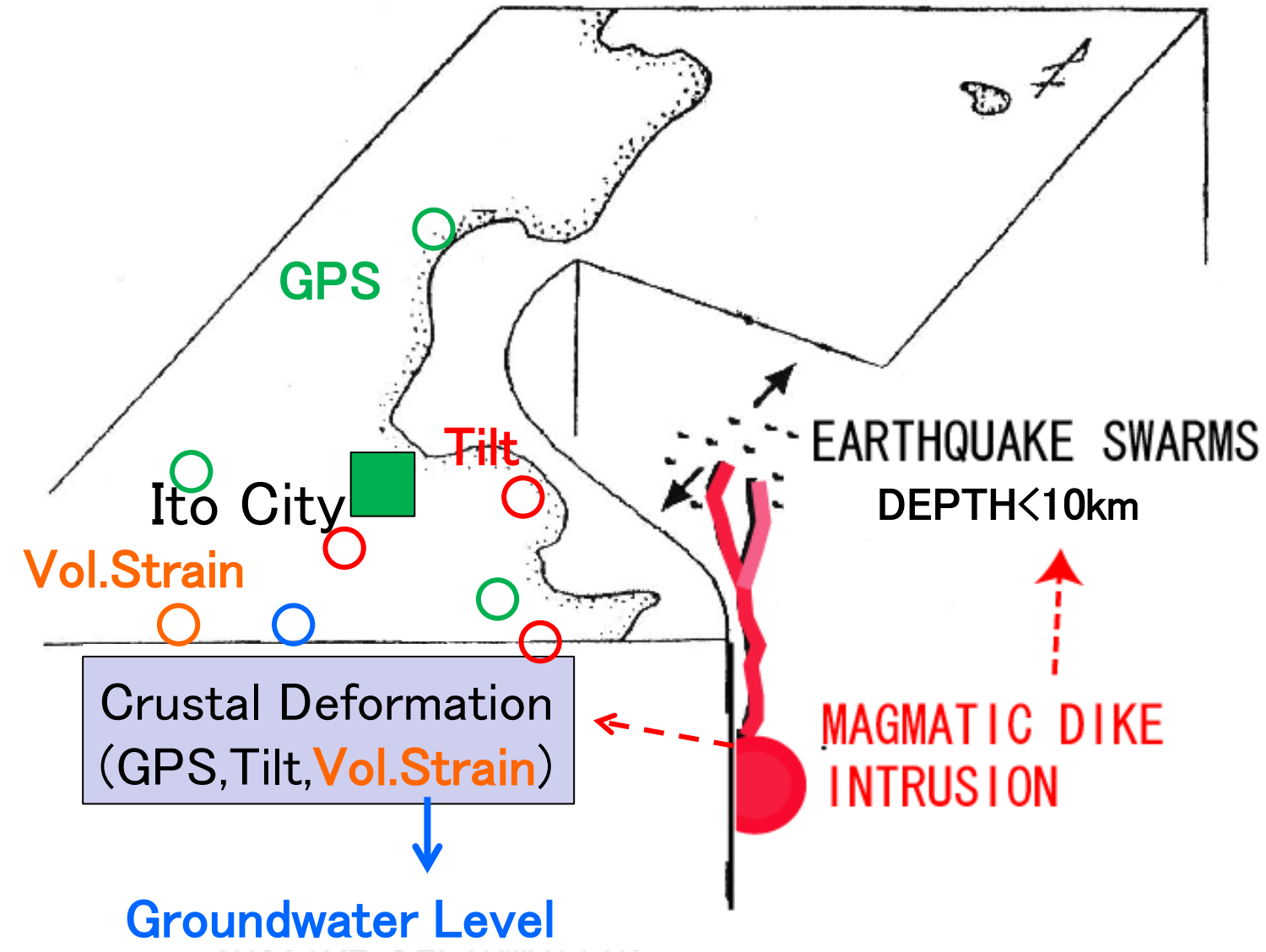
(2009/12/9-12/15) - (2009/12/21-12/27)

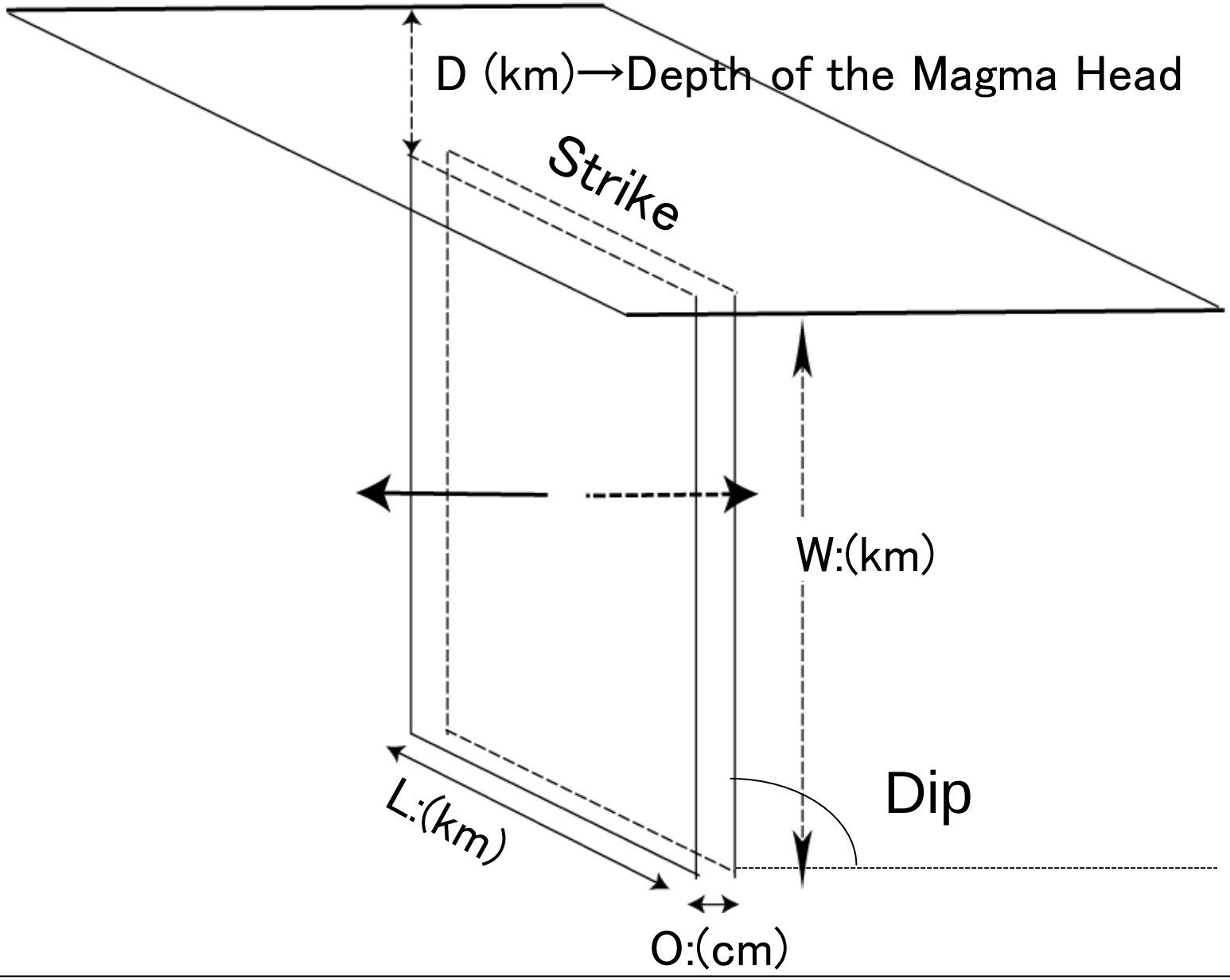
Horizontal



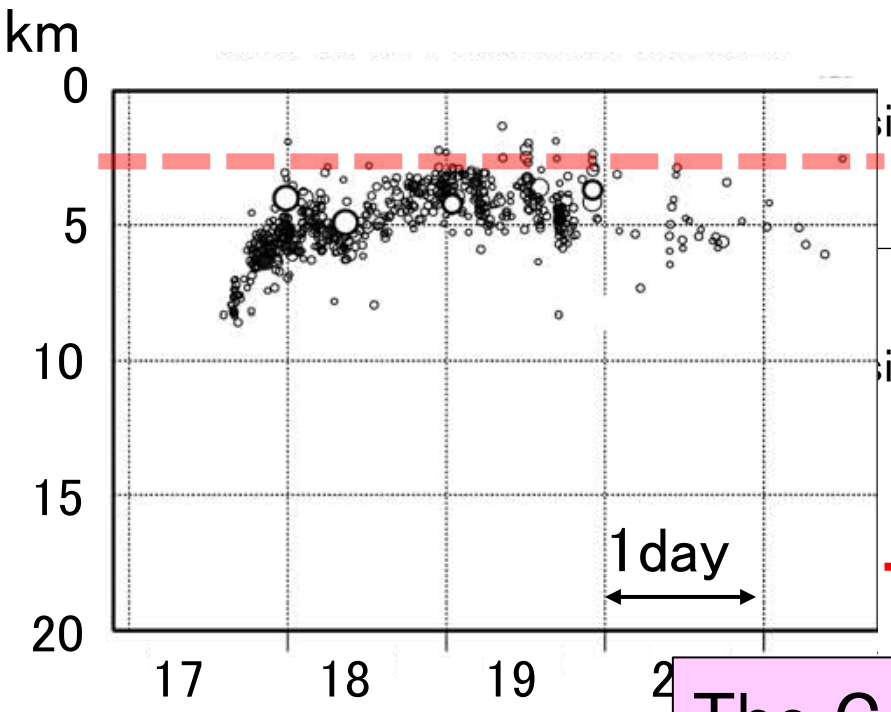
Vertical




GPS
Tilt
Ito City
Vol.Strain
EARTHQUAKE SWARMS
DEPTH<10km
Crustal Deformation
(GPS,Tilt,Vol.Strain)
MAGMATIC DIKE
INTRUSION
Groundwater Level

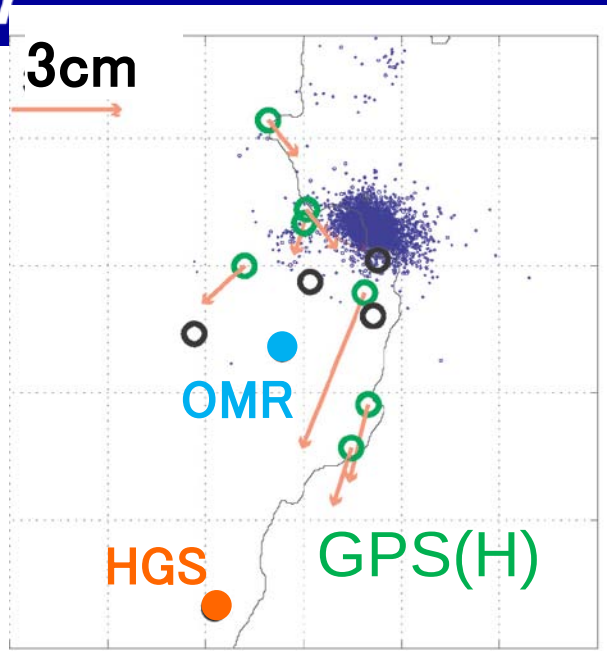

D (km)→Depth of the Magma Head
Strike
W:(km)
Dip
L:(km)
O:(cm)

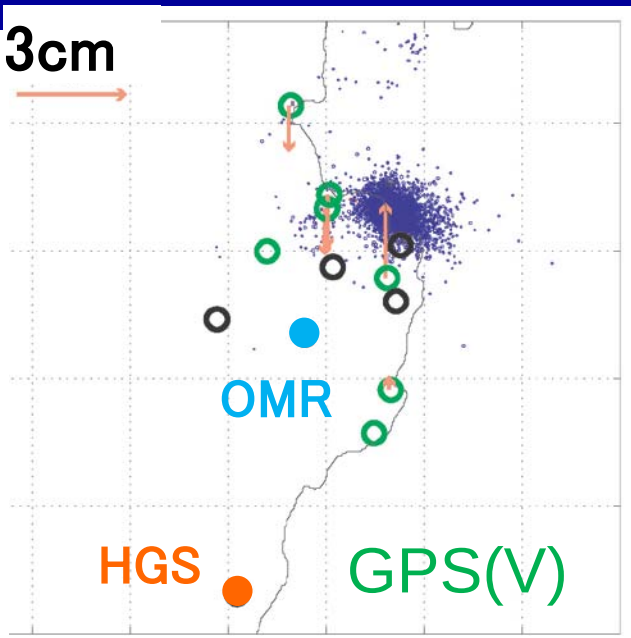
	Start	End	OBS.	F.Type	Strike (Deg.)	Dip (Deg.)	D (km)	L (km)	W (km)	O (cm)	Vol. 1E6m3
JMA1	12/16	12/18	V.STRAIN	Tensile	120	91	3.5	1.3	3.2	53	2.2
JMA2	12/18	12/20		Tensile	135	90	3.0	2.1	0.5	220	2.3
NIED1	12/17	12/18	Tilt	Tensile	127	108	1.9	3.0	5.3	31	4.9
NIED2	12/18	12/21		Tensile	129	90	2.4	0.6	1.1	210	1.4
				ile	110	90	1.0	4.3	3.0	100	12.9
				ile	122	95	2.4	1.0	5.5	66	3.6



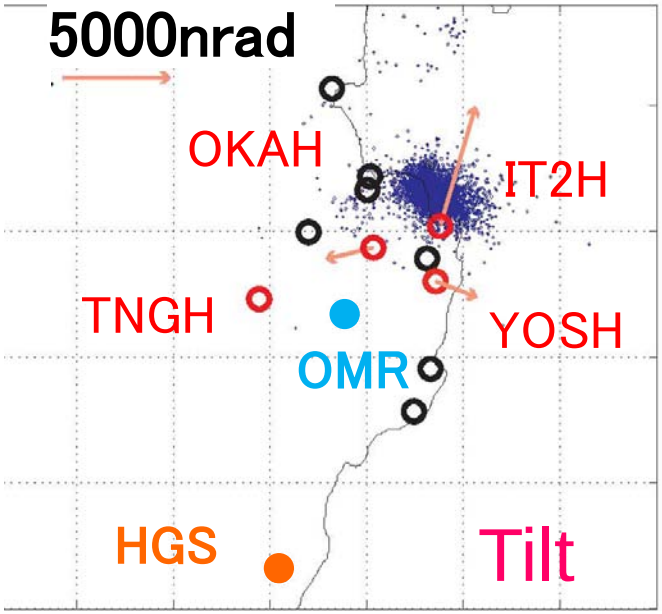
→ 2-3km

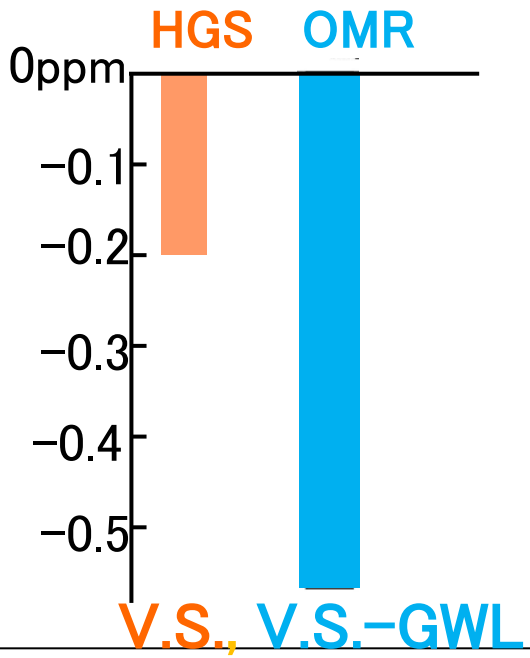
The Comprehensive Model is Needed.


3cm
OMR
HGS
GPS(H)


3cm
OMR
HGS
GPS(V)

5km


5000nrad
OKAH
IT2H
TNGH
YOSH
OMR
HGS
Tilt


HGS
OMR
0ppm
−0.1
−0.2
−0.3
−0.4
−0.5
V.S.,
V.S.−GWL

A Joint Analysis for the Comprehensive Model

1.Method of Weighted Least Squares

$\sum WiRi^2 \rightarrow$ Minimum

Ri=(Observed Value − Calculated Value)

Wi:Weight = $1/\sigma i^2$ σi:Noise Level→$WiRi^2$:Non-Dim.

- Each Noise Level . (n: 1E-9),

V.Strain:**22**nstrain, V.Strain from GWL :**88** nstrain

Tilts:43-355 nrad **GPS-H: 1cm GPS-V: 2.5cm (Temporary)**

2.Grid Search : Initial Position and Shape←Hypocenter

Depth[km] :	2 − 12,	Δ :2 →	1
Dip[deg] :	**60** − 100,	5 →	1
Strike[deg]:	**90(270)** − **130(310)**,	5 →	1
Lon[deg] :	139.1 − 139.18,	0.02 →	0.01
Lat[deg] :	34.92 − 35.0,	0.02 →	0.01
Length[km] :	**1** − 8 ,	2 →	1
Width[km] :	2 − 8 ,	2 →	1
Opening[cm]:	0 − 100,	10 →	0.5

	Start	End	OBS.	F.Type	Strike (Deg.)	Dip (Deg.)	D (km)	L (km)	W (km)	O (cm)	Vol. 1E6m3
JMA1	12/16	12/18	V.STRAIN	Tensile	120	91	3.5	1.3	3.2	53	2.2
JMA2	12/18	12/20		Tensile	135	90	3.0	2.1	0.5	220	2.3
NIED1	12/17	12/18	Tilt	Tensile	127	108	1.9	3.0	5.3	31	4.9
NIED2	12/18	12/21		Tensile	129	90	2.4	0.6	1.1	210	1.4
GSJ, AIST	12/16	12/20	W,L V.Strain	Tensile	110	90	1.0	4.3	3.0	100	12.9
GSI1	12/9-12/15	12/21-12/27	GPS and Other Geodetic Measureme	Tensile	122	95	2.4	1.0	5.5	66	3.6

	Start	End	OBS.	F.Type	Strike (Deg.)	Dip (Deg.)	D (km)	L (km)	W (km)	O (cm)	Vol. 1E6m3
JMA1	12/16	12/18	V.STRAIN	Tensile	120	91	3.5	1.3	3.2	53	2.2
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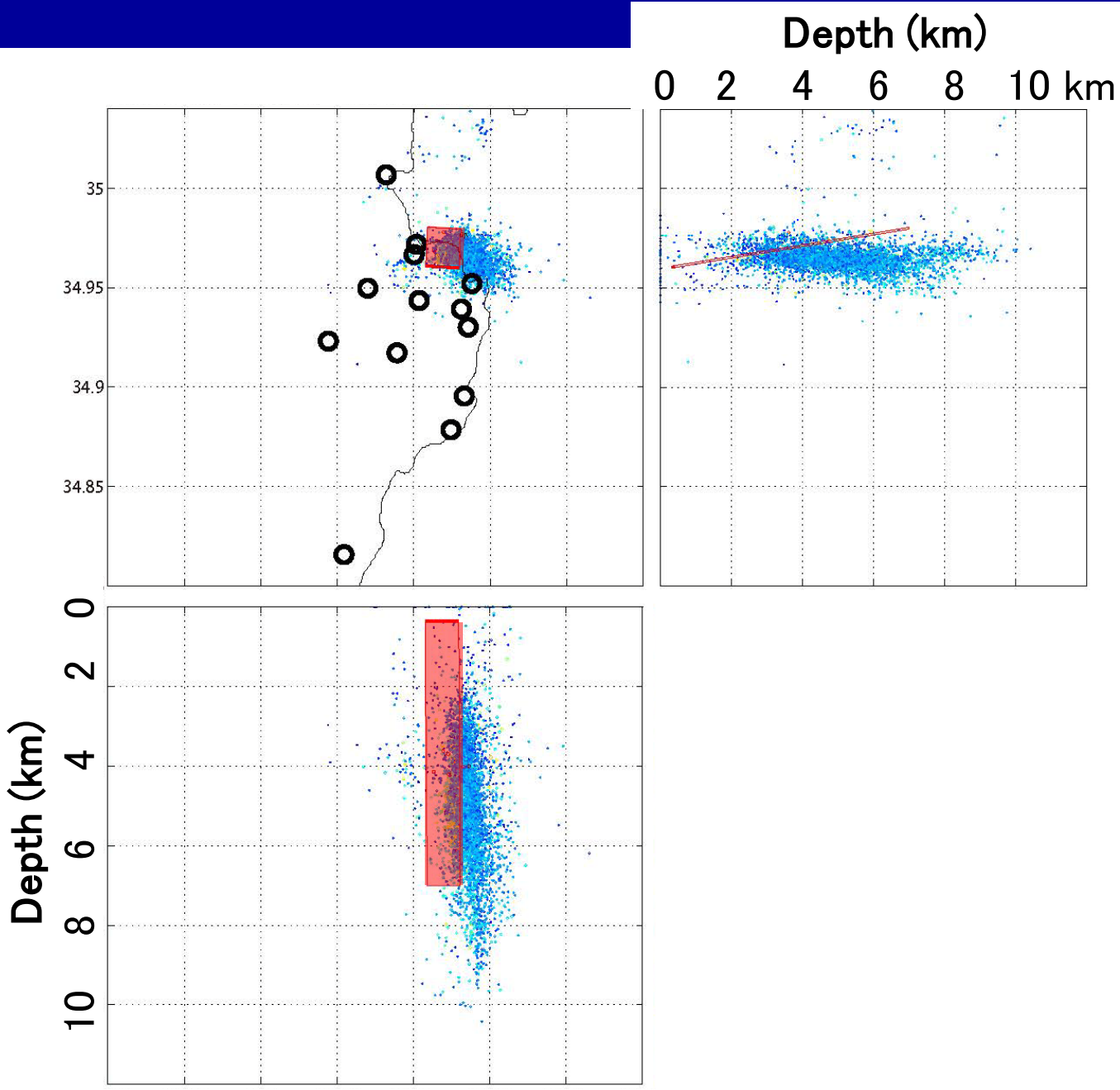
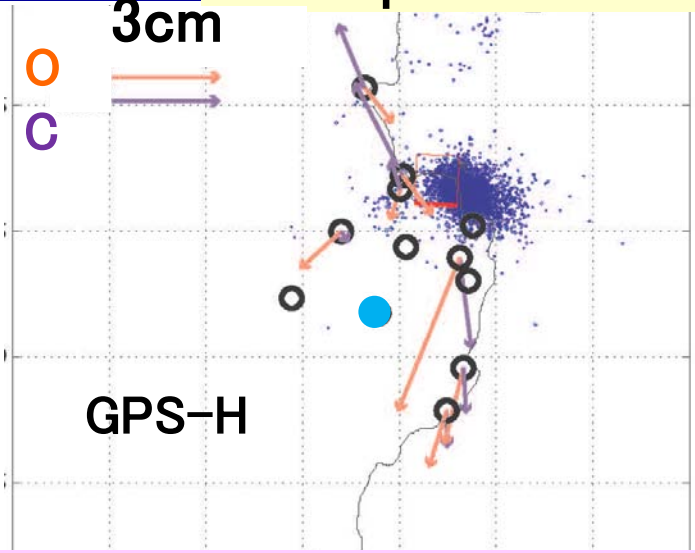
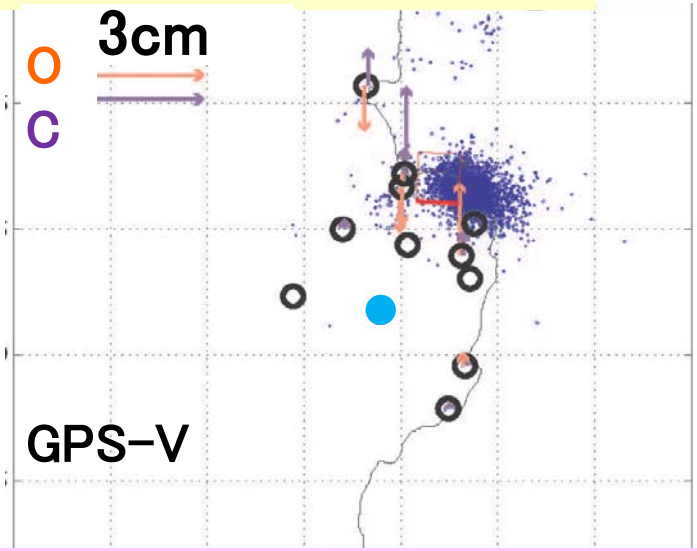
GSJ, AIST	12/16	12/20	W,L V.Strain	Tensile	110	90	1.0	4.3	3.0	100	12.9
GSI1	12/9-12/15	12/21-12/27	GPS and Other Geodetic Measureme	Tensile	122	95	2.4	1.0	5.5	66	3.6
Com-Model	12/17	12/21	Tilt GWL: V.Strain、GPS	Tensile	93	72	**0.3**	2.0	7.0	**22**	**3.1**

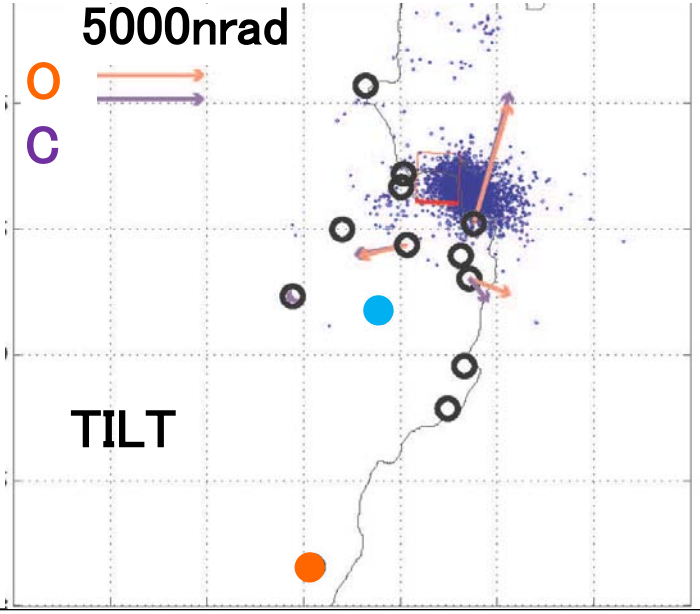

Depth (km)
0 2 4 6 8 10 km
35
34.95
34.9
34.85
Depth (km)
0 2 4 6 8 10

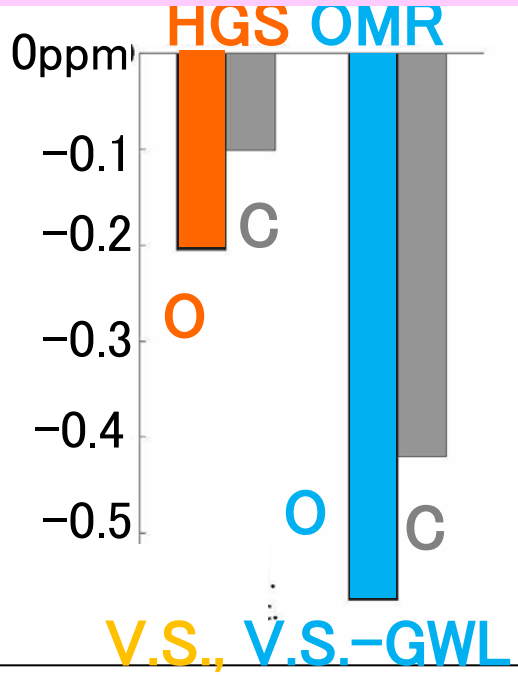
Comparison of Cal.V with Obs.V.





Matching of GPS Data is Worse Because of S/N is Worse.





Conclusion

・The Earthquake Swarms Have Repeatedly Occurred off the East Coast of Izu Peninsula Since 1978. They Have Been Approaching Ito City. The Swarms are Caused by the Magmatic Dike Intrusion, Which Induced Crustal Deformation and Groundwater Change. If the Head of the Magma Reach the Surface, Which Means a Volcanic Eruption, Severe Damage will Occur at Ito City. So It Is Important to Grasp the Position of the Magma Head by a Comprehensive Model Explaining All the Data. We Suggested one Method to Make the Comprehensive Model.

・In the Case of the Swarms in Dec.2009, Our Comprehensive Model Shows the Depth of the Magma Head was **0.3km**, Which was Much Shallower than that Inferred From the Seismicity. We will Examine the Assumption of the Model and Parameters and Try to Grasp the Position of the Magma Head More Precisely.