

Observation of crustal deformation of the Japanese islands by GEONET

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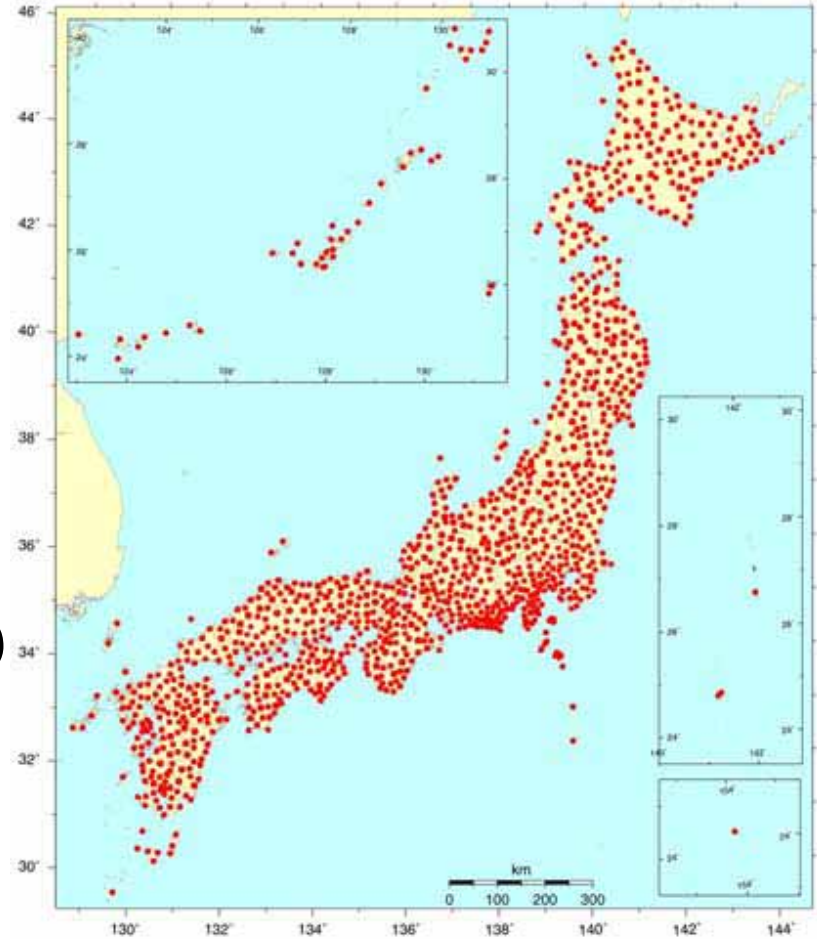
GEONET (GPS Earth Observation Network System)

Purposes

- Crustal deformation monitoring
- Provide reference station for Geodetic survey

Observation Network

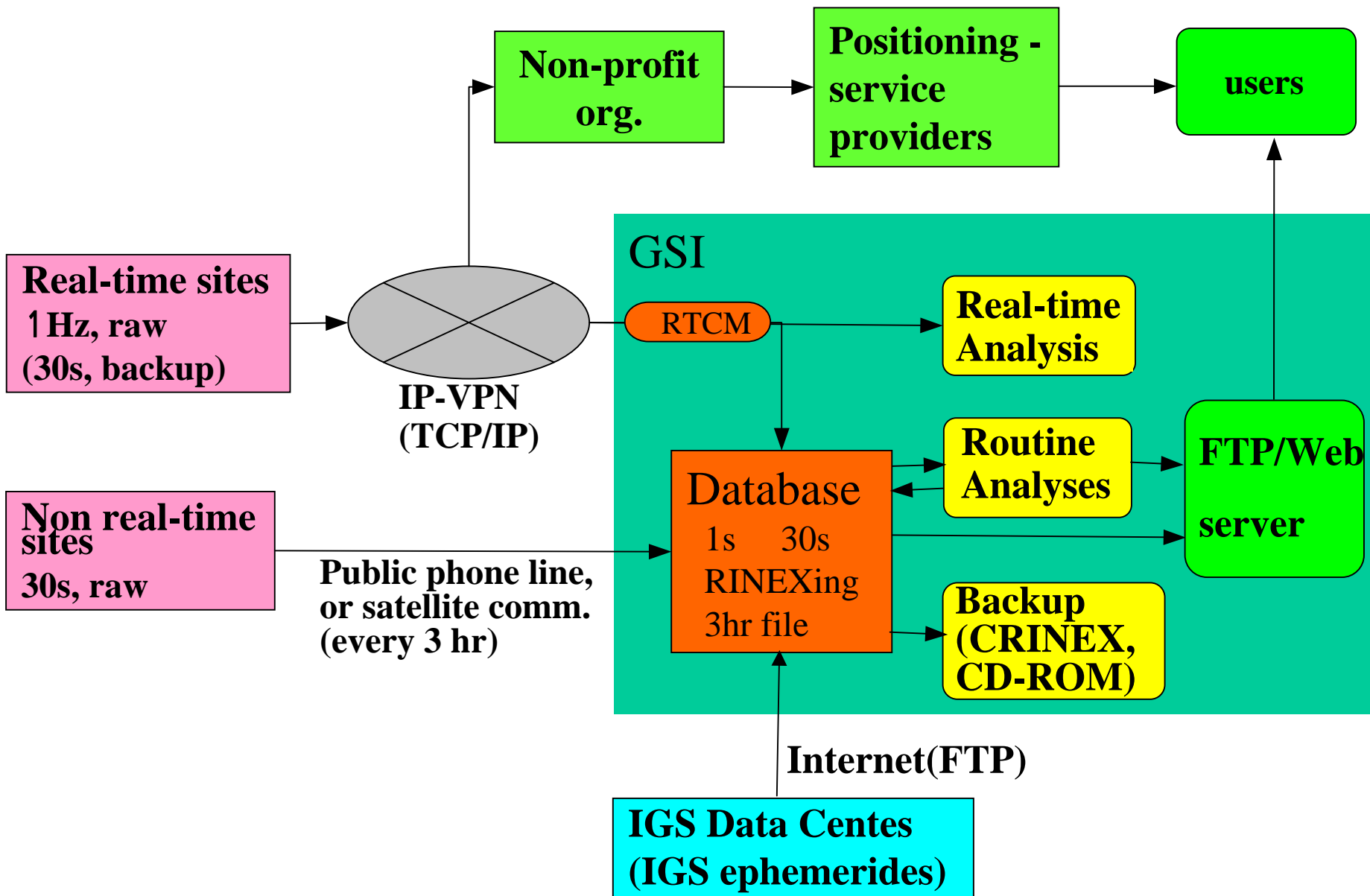
- 1231(+)sites (as of 2006)
- Site separation:~20 km



GEONET station



- Stainless steel pillar (5m tall)
- Choking Antenna
- Dual frequency receiver
- 24hr observation
- 1 Hz sampling
- Real-time data transfer



Data Analysis

- Routine analyses (whole network)
 - Three types of analyses

type	Sess.	Freq.	eph.	remarks
Quick	6hr	every 3 hr	IGU	near real-time
Rapid	24hr	daily	IGU	
Final	24hr	weekly	IGS	

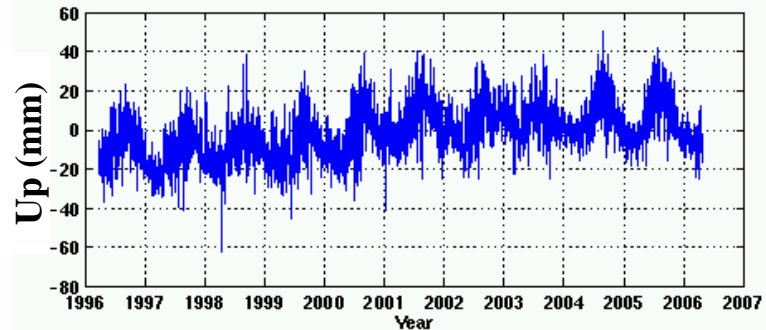
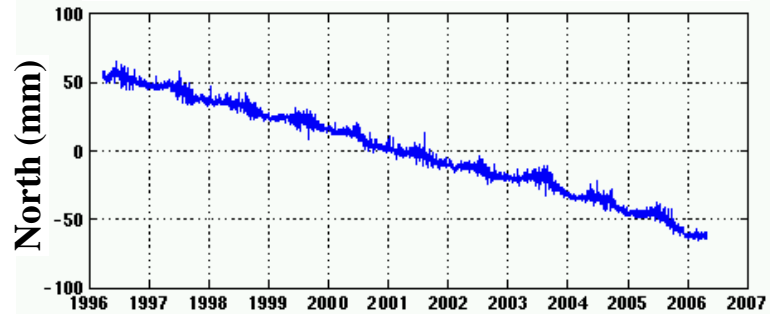
- Emergency analysis (for selected sites <50)
 - To detect large movements ($> 5\text{cm}$) within 5 min.
 - Software: RTNET (GPS Solutions Inc.)
 - orbit: IGU products
 - Real time/post-processing

Analysis Strategies (F2, R2, Q2)

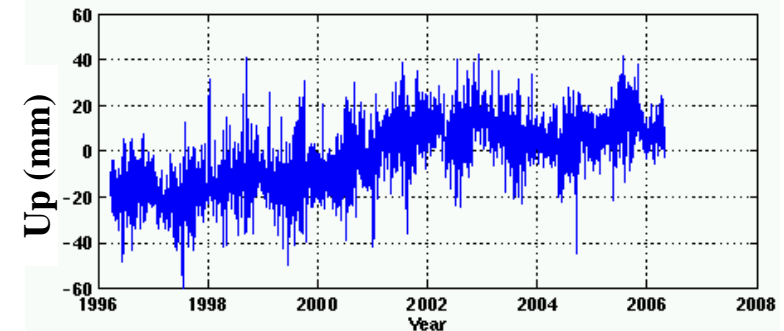
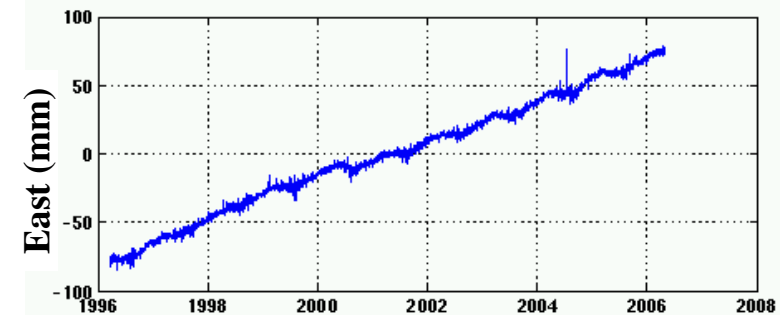
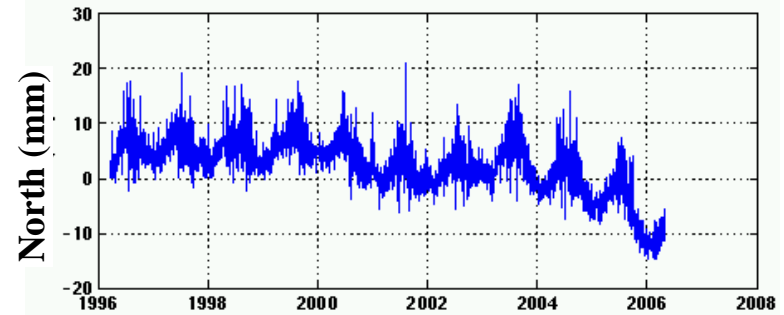
Software	BERNESE Ver. 4.2
Observable	-Phase LC (ionosphere-free) -double difference -Antenna-radome calibration (for each station type)
Satellite orbit & EOP	-IGS final products (for F2) -IGS Ultra Rapid products (for R2 & Q2)
Reference frame	-ITRF2000 (constrained stations, orbits, EOP) -A station at Tsukuba is fixed
Model	-IERS conventions 1996 -Ocean Loading Model (Matsumoto et al., 2000) -Niell's (1996) Mapping Function -etc.
Estimated parameters	-Station coordinates (once/session) -Troposphere delay (every 3 hr) -Phase ambiguities (resolved, finally eliminated)

Time series of site coordinates (Tobishima st.)

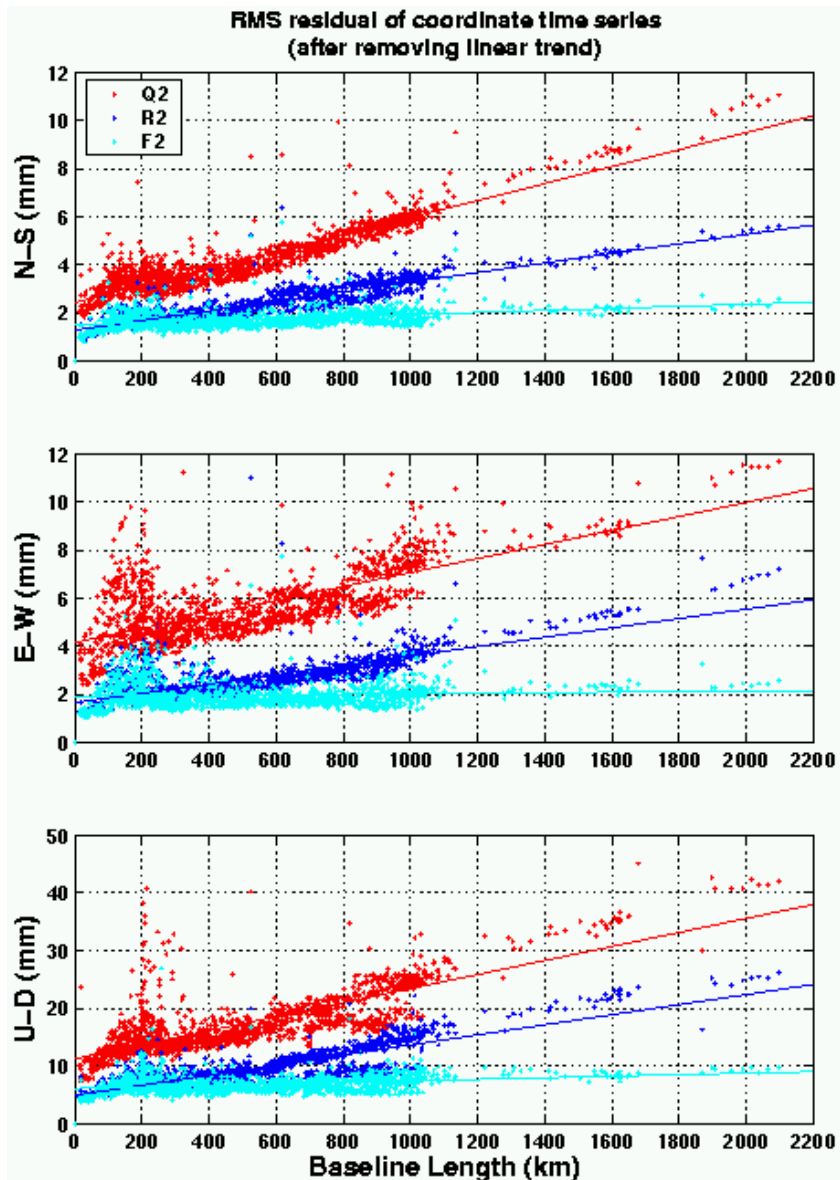
Site movement in ITRF2000



Relative movement to Yasato st.



Short-term Repeatability (2004/02/1-04/30)



$$s.d = a + b \times L$$

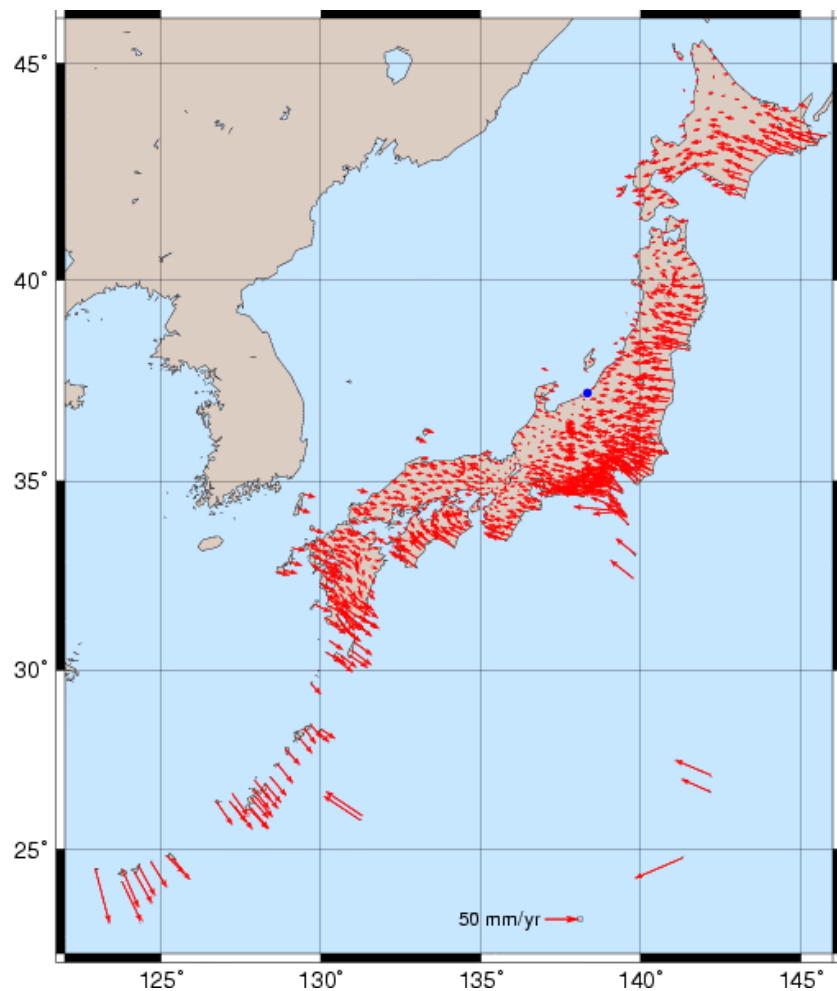
	a(mm)	b(ppb)
F2	NS	1.5
	EW	1.9
	UD	6.1

	a(mm)	b(ppb)
R2	NS	1.3
	EW	1.7
	UD	4.9

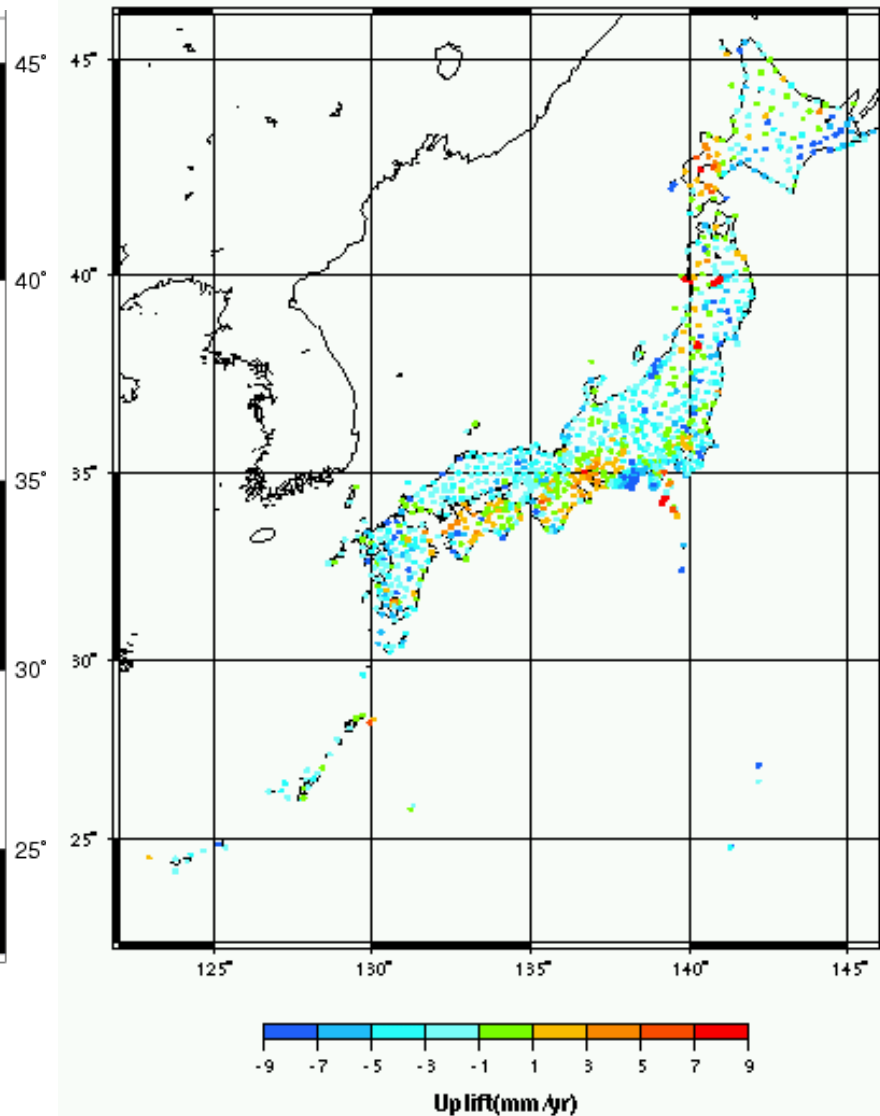
	a(mm)	b(ppb)
Q2	NS	2.4
	EW	4.2
	UD	11.3

Velocity field of Japan (1996.3-1999.12)

Horizontal

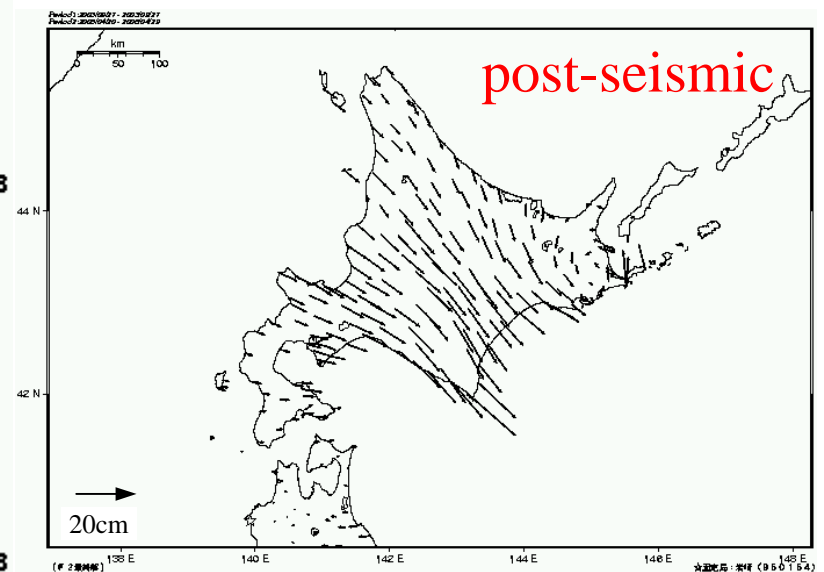
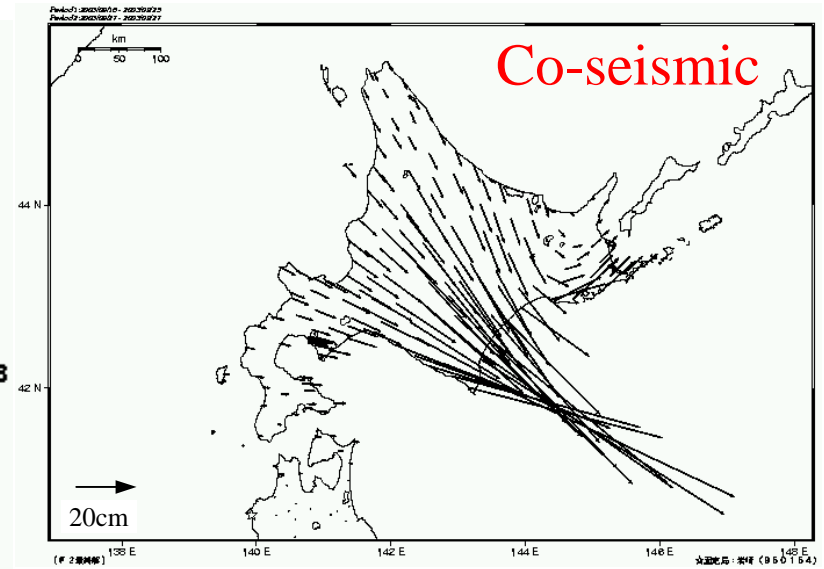
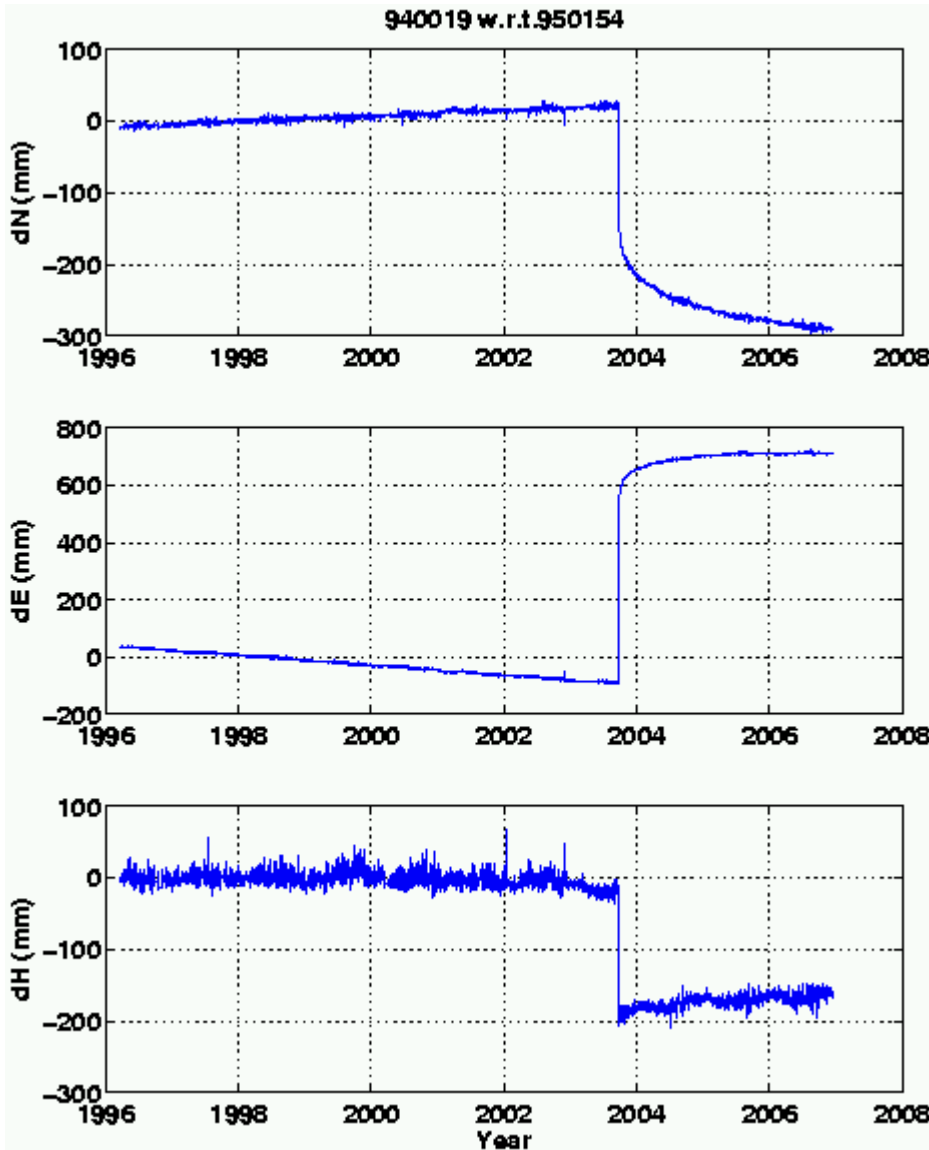


Vertical



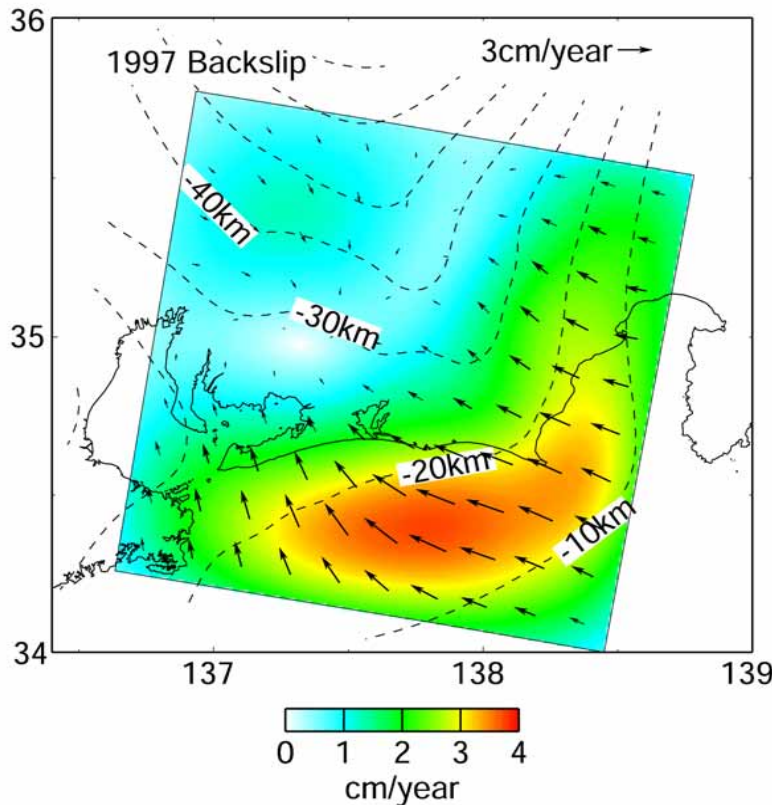
Co-seismic & post-seismic crustal deformation

(The 2003 Tokachi Earthquake, Sep. 26, 2003, M8.0)

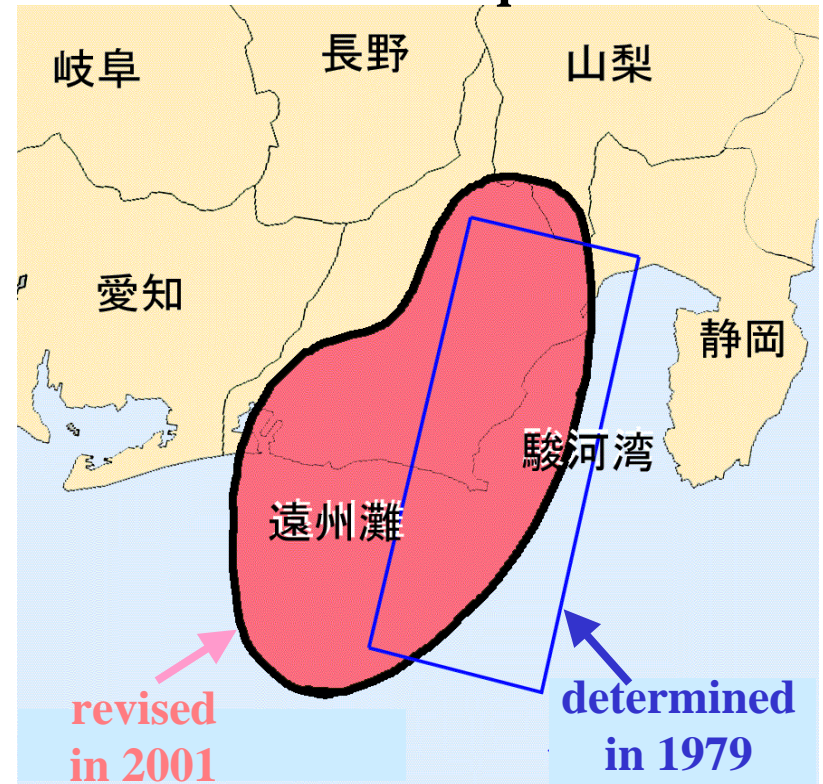


Inter-plate coupling asperity

source area of the hypothesized
Tokai Earthquake

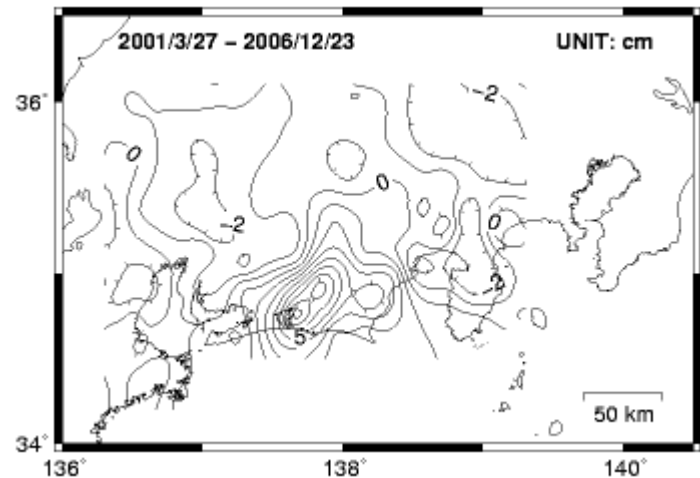
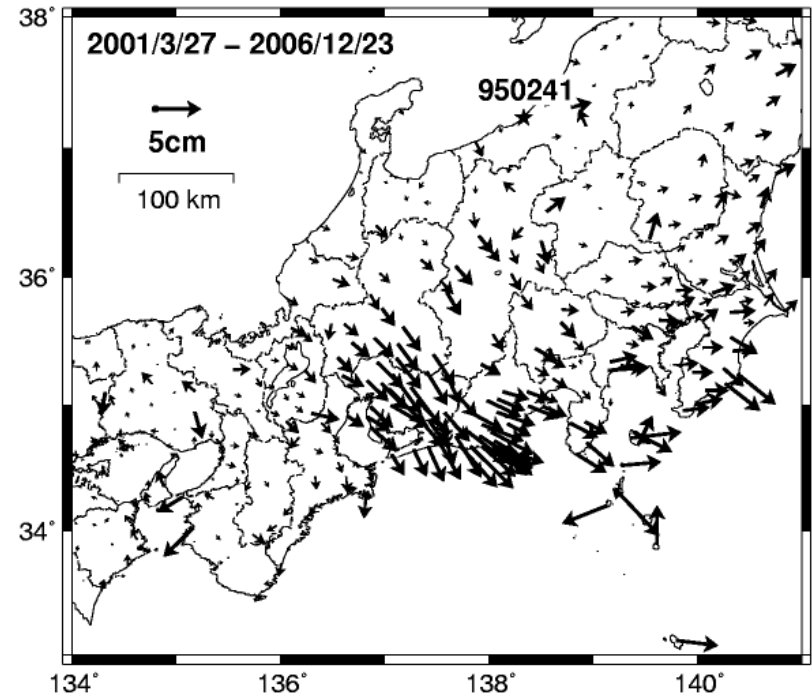
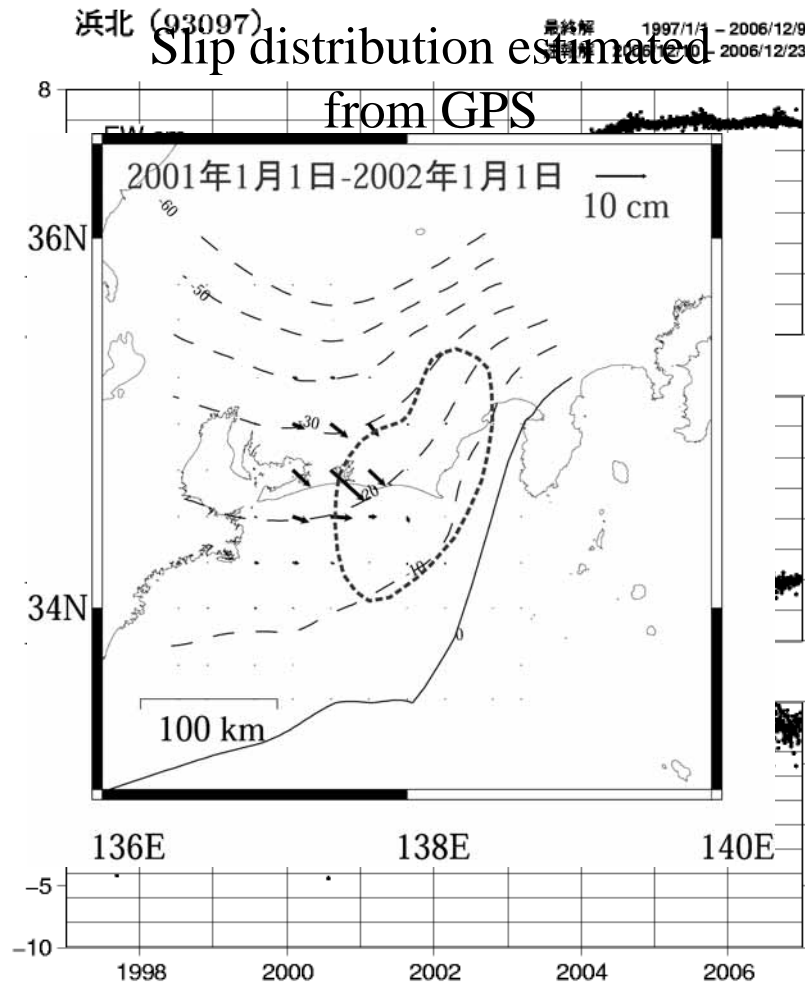


Sagiya(1999)



(Central Disaster Prevention Council)

Slow slip in the Tokai area(2001 ~ 2006)



Seismic/Volcanic Events that GEONET detected Crustal deformation (1994 ~ 2002)

1994.10. 4.	East-off Hokkaido EQ(M8.1)
1994.12.28.	Far-off Sanriku EQ(M7.5)
1995. 1.17.	Kobe EQ (M7.2)
1995.10.	EQ swarm in eastern Izu peninsula
1996. 5.	Slow EQ around Boso peninsula
1996. 8.11	Miyagi-Akita EQ (M5.9)
1996.10.	EQ swarm in eastern Izu peninsula
1996.10.19.	Hyuga-nada EQ (M6.6)
1996.12. 3.	Hyuga-nada EQ (M6.6)
1997.	Slow EQ around Bungo Suido
1997. 3.	EQ swarm in eastern Izu peninsula
1997. 3.26.	Northwest Kagoshima EQ (M6.3)
1997. 5.13.	Northwest Kagoshima EQ (M6.2)
1998. 4.	EQ swarm in eastern Izu peninsula
1998. 9. 3	Iwate EQ (M6.1)

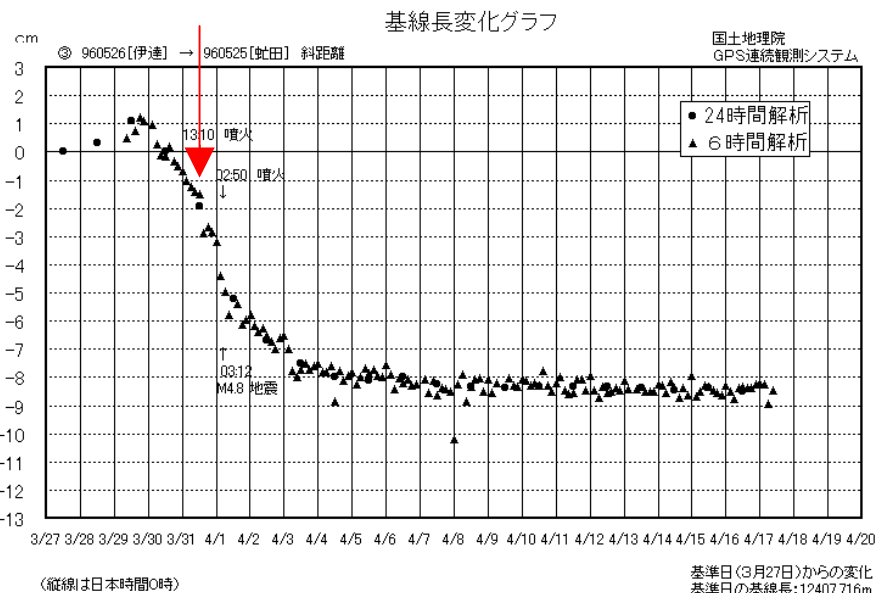
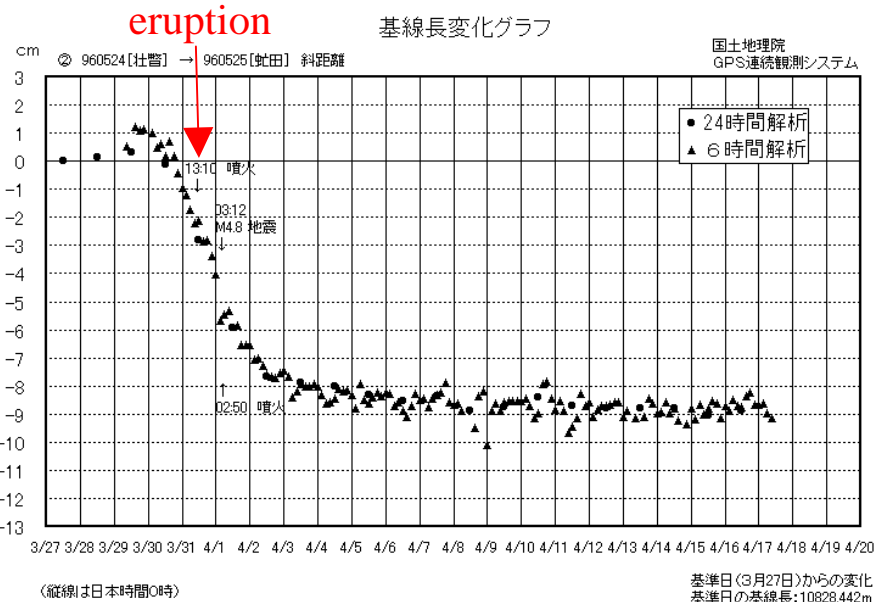
2000. 3.31.	Eruption of Mt Usu
2000. 6-	Volcanic and seismic activities of Miyake island, Niijima-Kouzusima area
2000.10. 6.	West Tottori EQ (M7.3)
2000.Fall (~ 2002)	Mt. Asama volcanic activities
2001. 3.24.	Geiyo EQ (M6.4)
2001. 6.	Hakone volcanic activities
2001. 7.	Slow EQ in Tokai are (~ 2006)
2001.10.	Volcanic activities around Izu-Ooshima island
2002. 5.	EQ swarm in eastern Izu peninsula
2002.10.	Slow EQ around Boso peninsula
2002.11. 3.	Off-Miyagi EQ (M6.1)

Seismic/Volcanic Events that GEONET detected Crustal deformation (2003 ~)

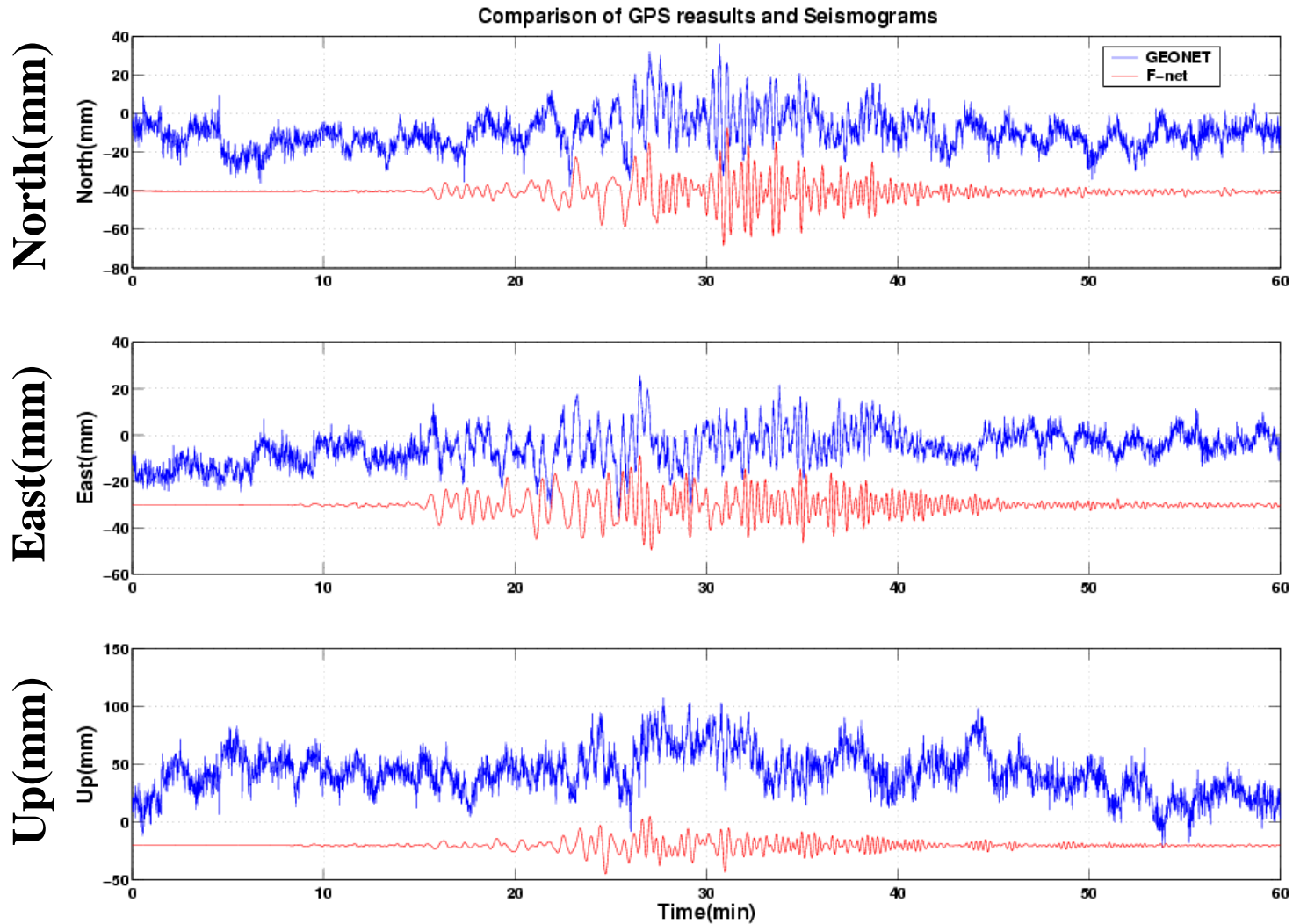
2003. 5.	EQ swarm in eastern Izu peninsula
2003. 5.26.	Off Miyagi EQ (M7.0)
2003. 7.26.	North Miyagi EQ (M6.2)
2003. 9.26.	Tokachi EQ (M8.0)
2003.10.	Slow EQ around Bungo Suido
2003.10.31	Off-Fukushima EQ (M6.8)
2004. 4-	EQ swarm in eastern Izu peninsula
2004. 9. 5.	SE off-Kii peninsula EQ (M7.4)
2004.10.23.	Central Niigata EQ (M6.8)
2004.11.29.	Off Kushiro EQ (M7.1)
2004.12. 6.	SE off-Nemuro EQ (M6.9)
2004.12.14.	South Rumoi EQ (M6.1)

2005. 3.20.	W off Fukuoka EQ (M7.0)
2005. 8.16.	Off Miyagi EQ (M7.2)
2005.10.19.	Off Ibaraki EQ (M6.3)
2005.12. 2.	Off Miyagi EQ (M6.6)
2006.1-5	EQ swarm in eastern Izu peninsula
2006.8-11	Hakone volcanic activities
2006.11.15	Kuril island EQ (M7.9)
2006.11.18	EQ Near Amami (M6.0)
2006.fall-	Rapid deformation of Iou-jima Island

Eruption of Usu volcano (Mar. 2000)



The off-Sumatra earthquake (Dec. 26, 2004)



Blue : GPS (GEONET, GSI)

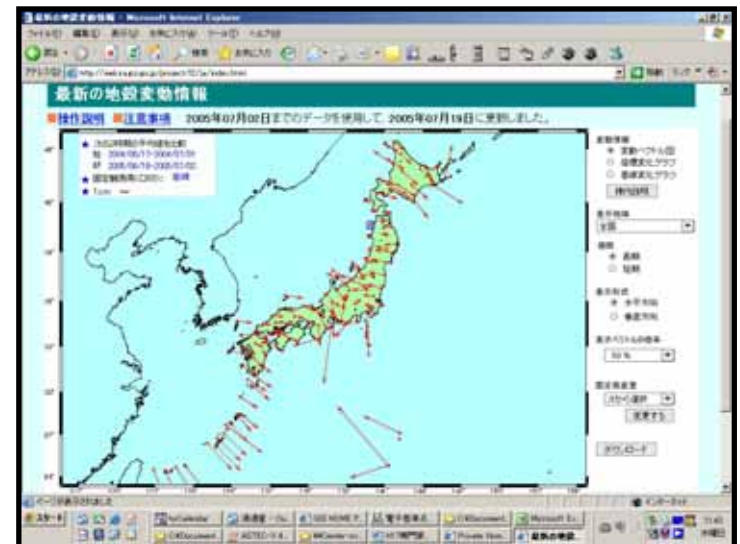
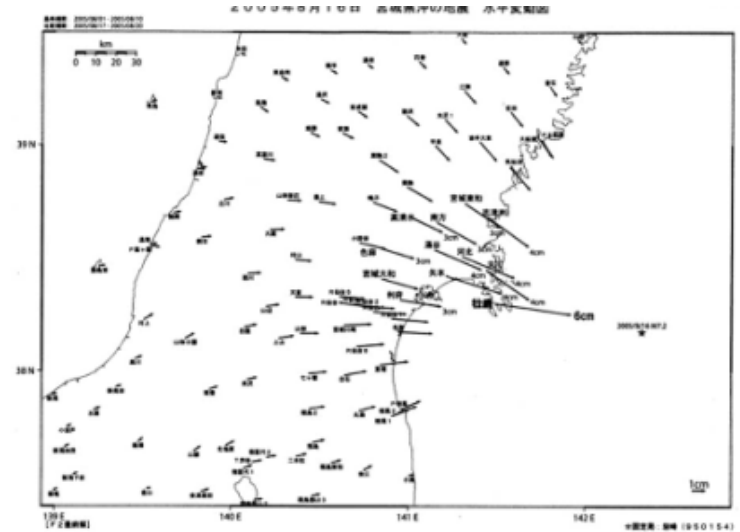
Red : Seismogram (F-net, NIED)

Crustal deformation monitoring by GPS

- GPS continuous monitoring provide information on
 - mechanism
 - Fault model, pressure source
 - transition
 - After-slip, silent earthquakes (slow events)
 - Volcanic activity
 - background
 - Plate motion
 - Inter-plate coupling

Provision of information on crustal deformation by GEONET

- Committees
 - The Earthquake Research Committee
 - The Coordinating Committee for Earthquake Prediction
 - The Coordinating Committee for Prediction of Volcanic Eruption
 - etc.
- monthly press release (Sep. 2003 ~)
- On Web
 - <http://mekira.gsi.go.jp/ENGLISH/>



Capability of GEONET as a tool for crustal deformation monitoring

- High density (~ 20km)
- High precision (h 2mm , v 1cm, daily solutions)
- Continuous Observation (24 hour/day)
 - can wait for events.
- Good at long-term phenomena, especially

Other applications of GEONET

- GPS: sensitive to many kinds of geophysical signals
- GEONET provide opportunities for a variety of applications of earth observation
 - An infrastructure of Earth Observations
 - Vertical coordinates sea level monitoring
 - Reference for seafloor crustal deformation observation
 - Calibration of InSAR
 - Troposphere estimates meteorology, climatology
 - Ionosphere monitoring
 - etc.
- Purpose of observation can be multiple
 - Easy to make linkage to other applications

Tidal stations equipped with GPS



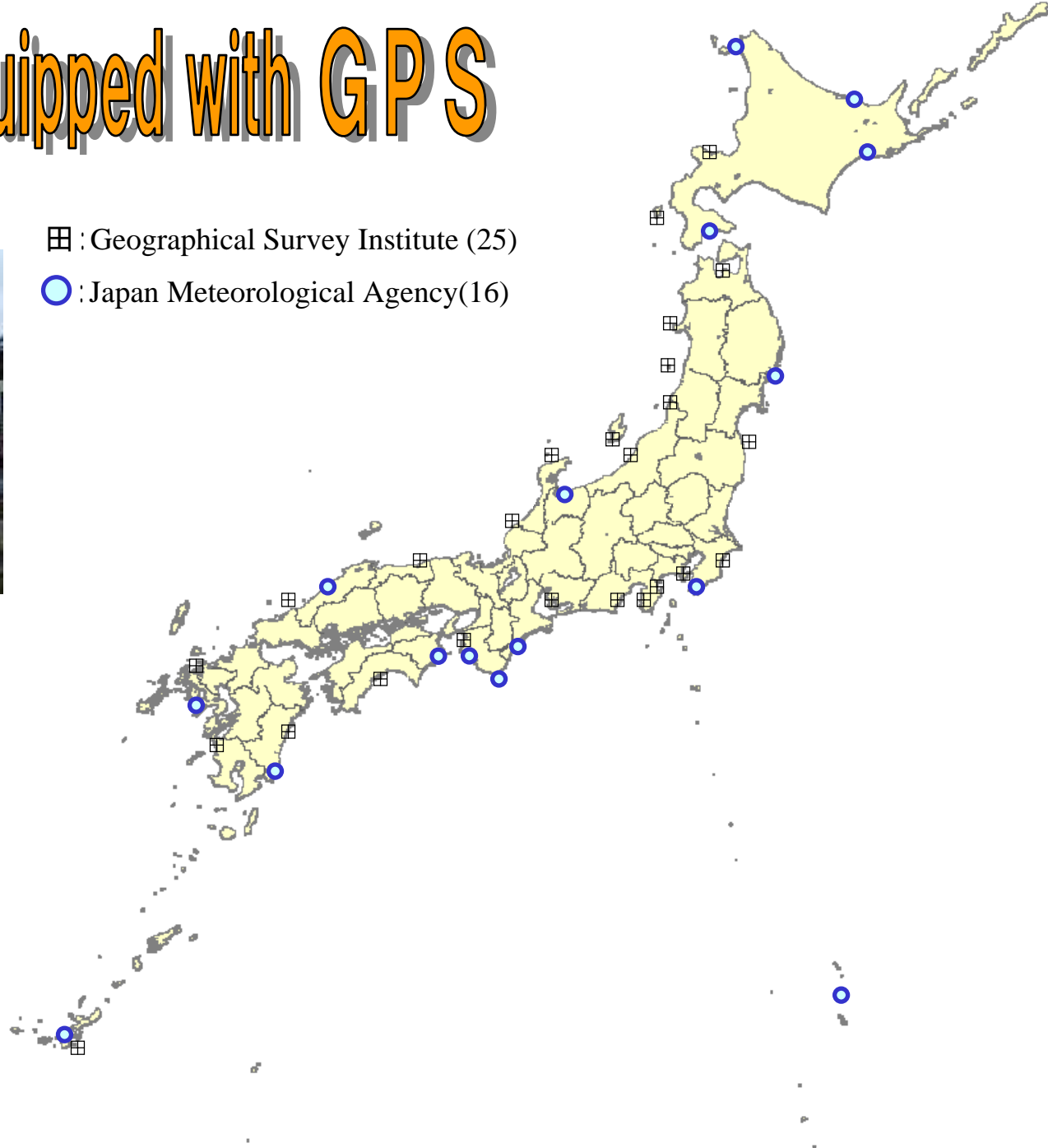
Tobishima



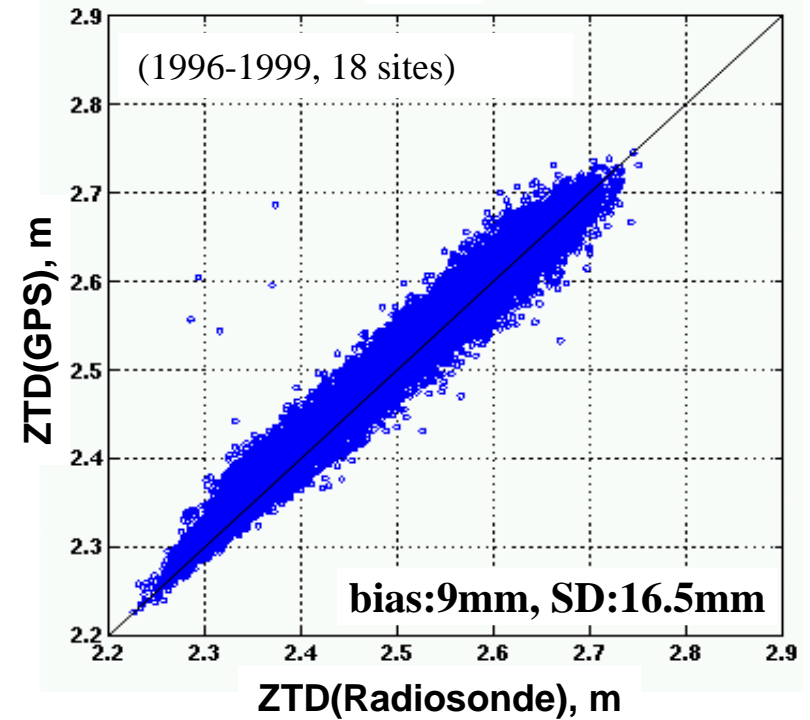
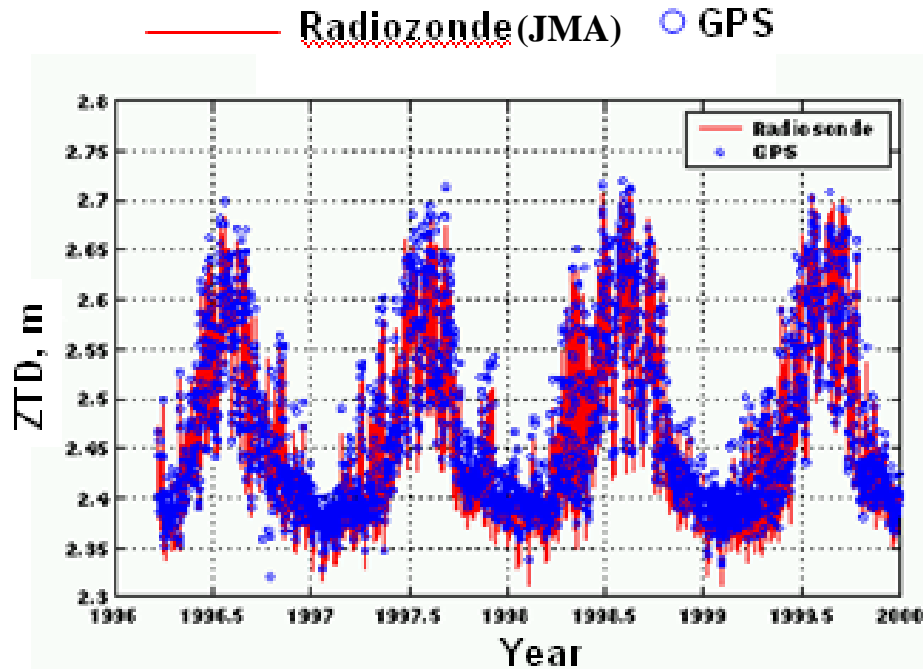
Aburatsubo

田 : Geographical Survey Institute (25)

○ : Japan Meteorological Agency (16)



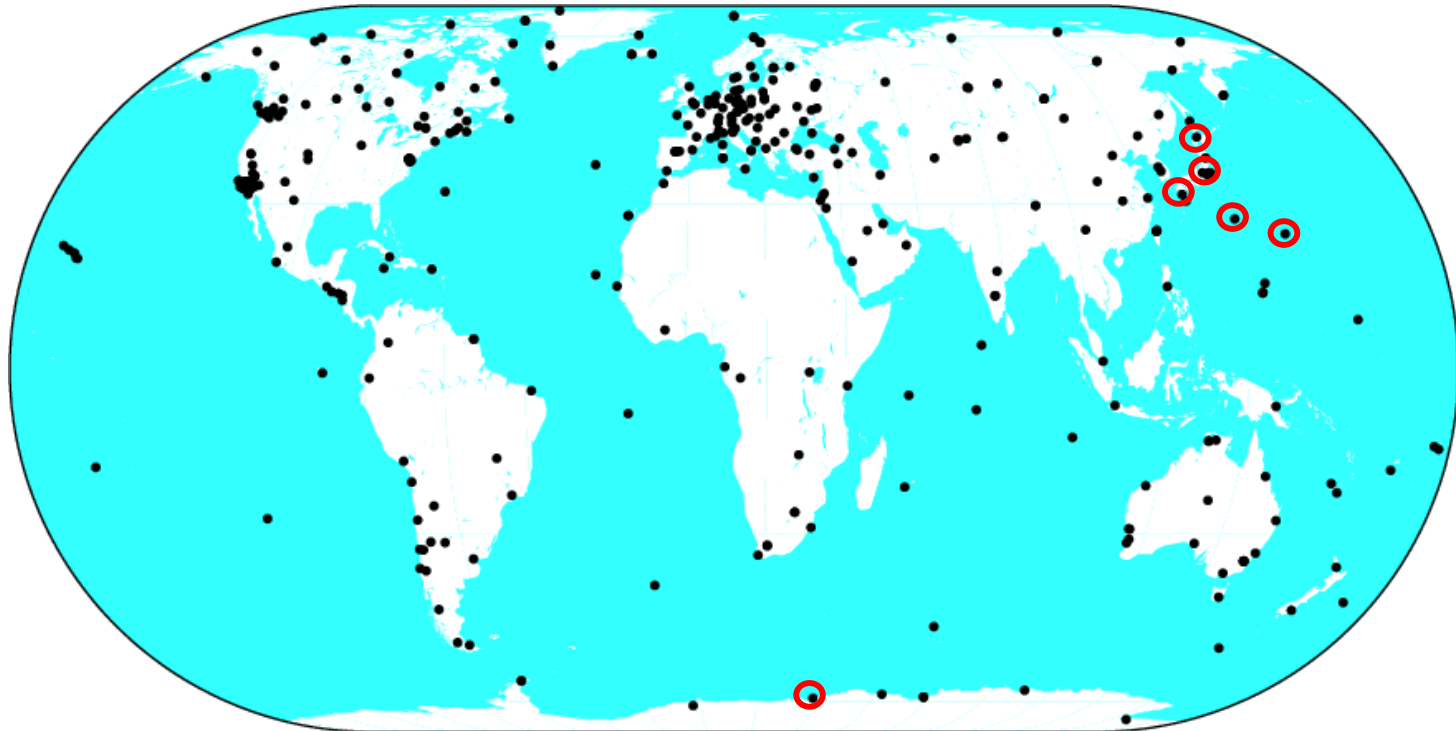
Comparison of GPS & Radiosonde



crustal deformation and environment

- Common requirements:
 - accuracy and calibration
 - long-term stability of observation system & geodetic reference frame
 - international cooperation
 - long term observation (>several tens of years)

The IGS Tracking Network



GMT 2006 Apr 24 17:32:45

- 380 sites (338 are active, as of Jan. 2007)
- GSI's contribution (7 sites):
TSKB, TSK2, AIRA, CCJM, MCIL, STK2, SYOG

Dual mission of GEONET

- Monitoring of Crustal deformation
- Social infrastructure
 - Maintaining geodetic reference frame of Japan
 - Providing reference coordinates and data for land survey & positioning
- Linkage to social service
 - Both missions are supporting each other
 - Appeal the necessities
 - Keep motivation of observation
 - one of keys of management for long term