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# The impact of the 2011 off the Pacific coast of Tohoku Earthquake on Tsukuba 32-m station

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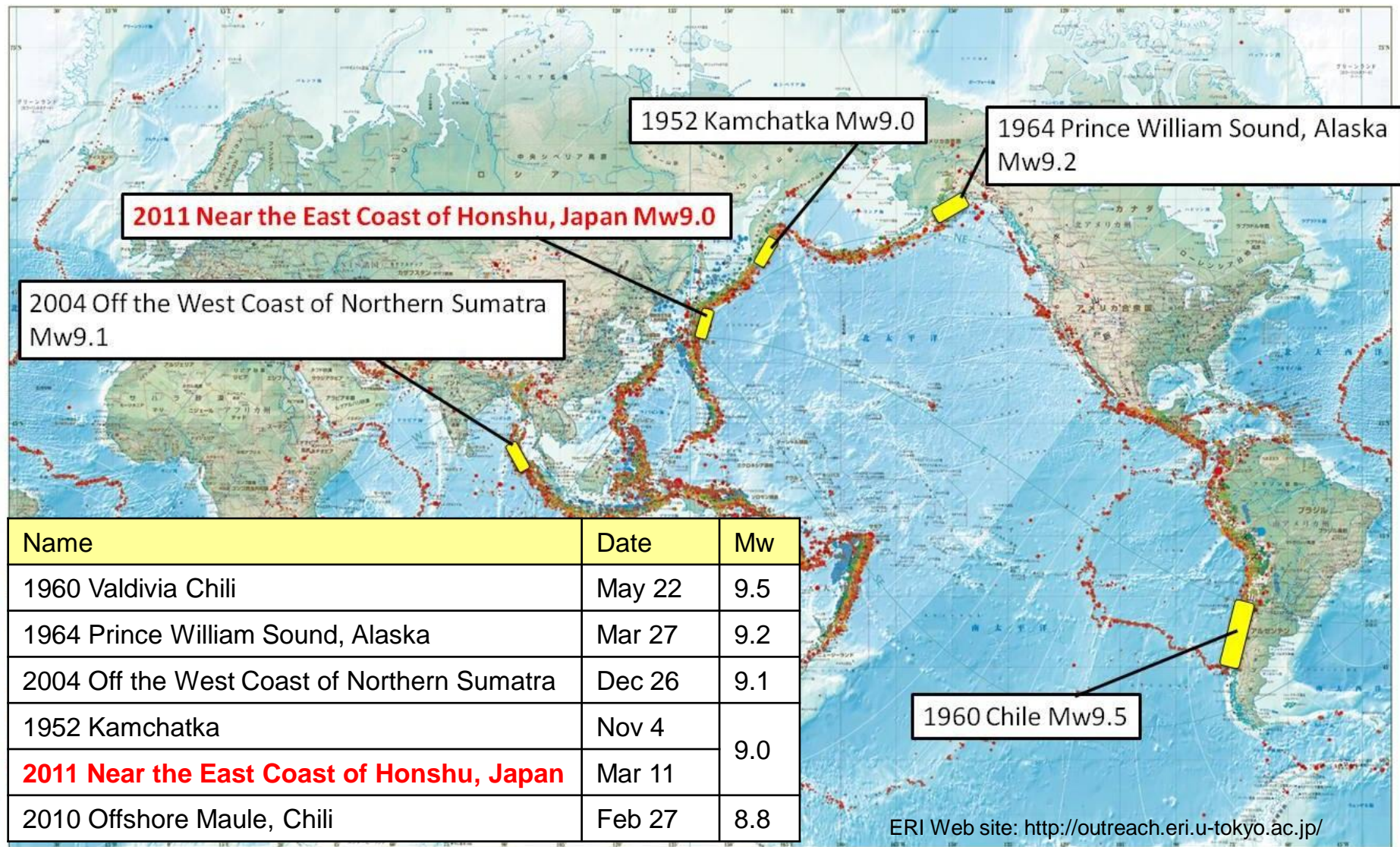
Geospatial Information Authority of Japan



# Contents

- Summary of the earthquake
  - Reviewing history of earthquakes in the world and Japan
  - Summarizing the Tohoku earthquake with general information and some pictures
- GPS results
- VLBI results
- Revision of control points

# Mega-Earthquakes in the world since 1990

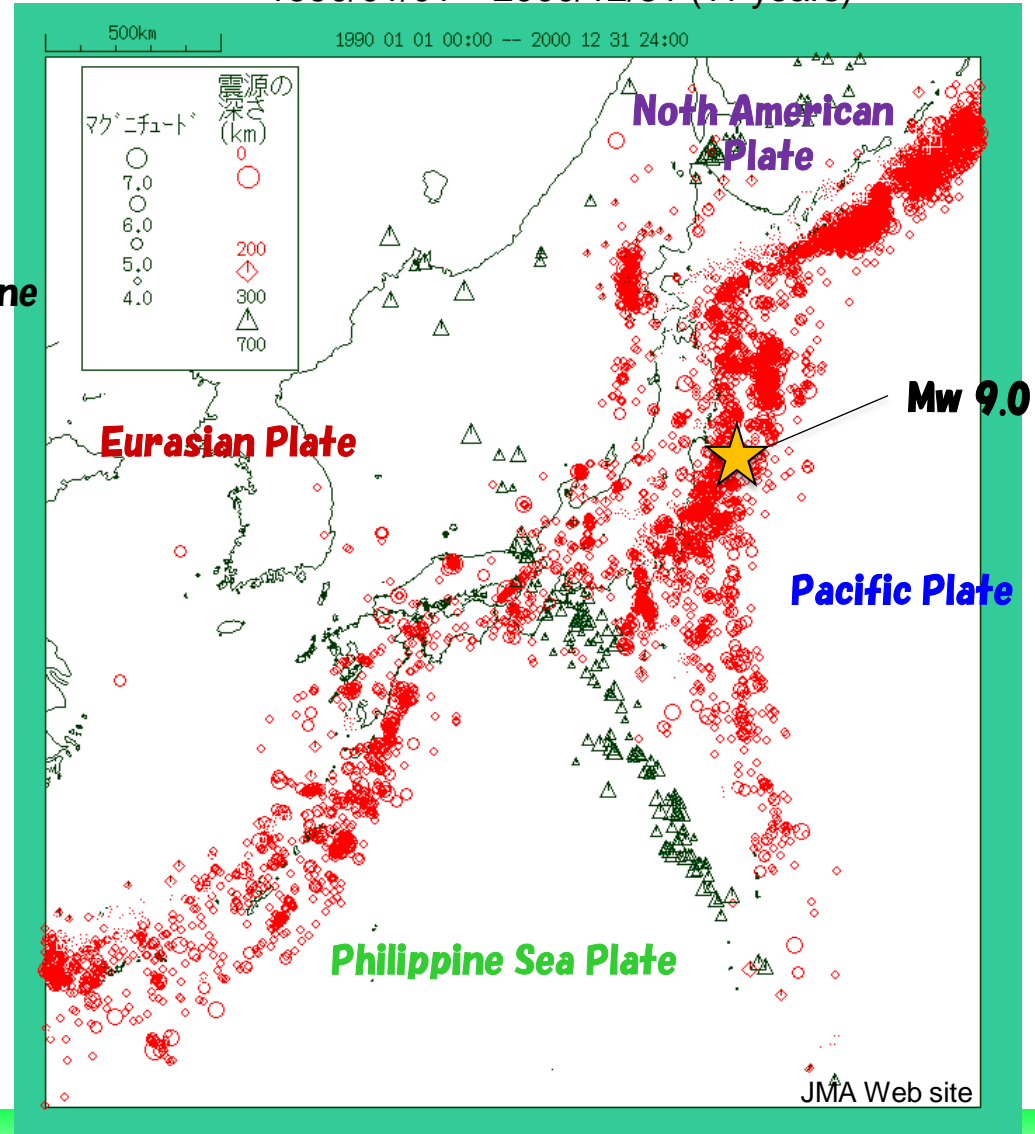


# Plate boundaries around Japan



4 tectonic plates covering the Japanese archipelago

1990/01/01 – 2000/12/31 (11 years)



# GSI VLBI antennas on each tectonic plates



**Shintotsukawa 3.8m**

APSG  
JADE



**Tsukuba 32m**

IVS-R1/R4/T2  
INT2/INT3  
RDV  
R&D  
CONT  
APSG  
JADE



IVS-T2  
APSG  
JADE

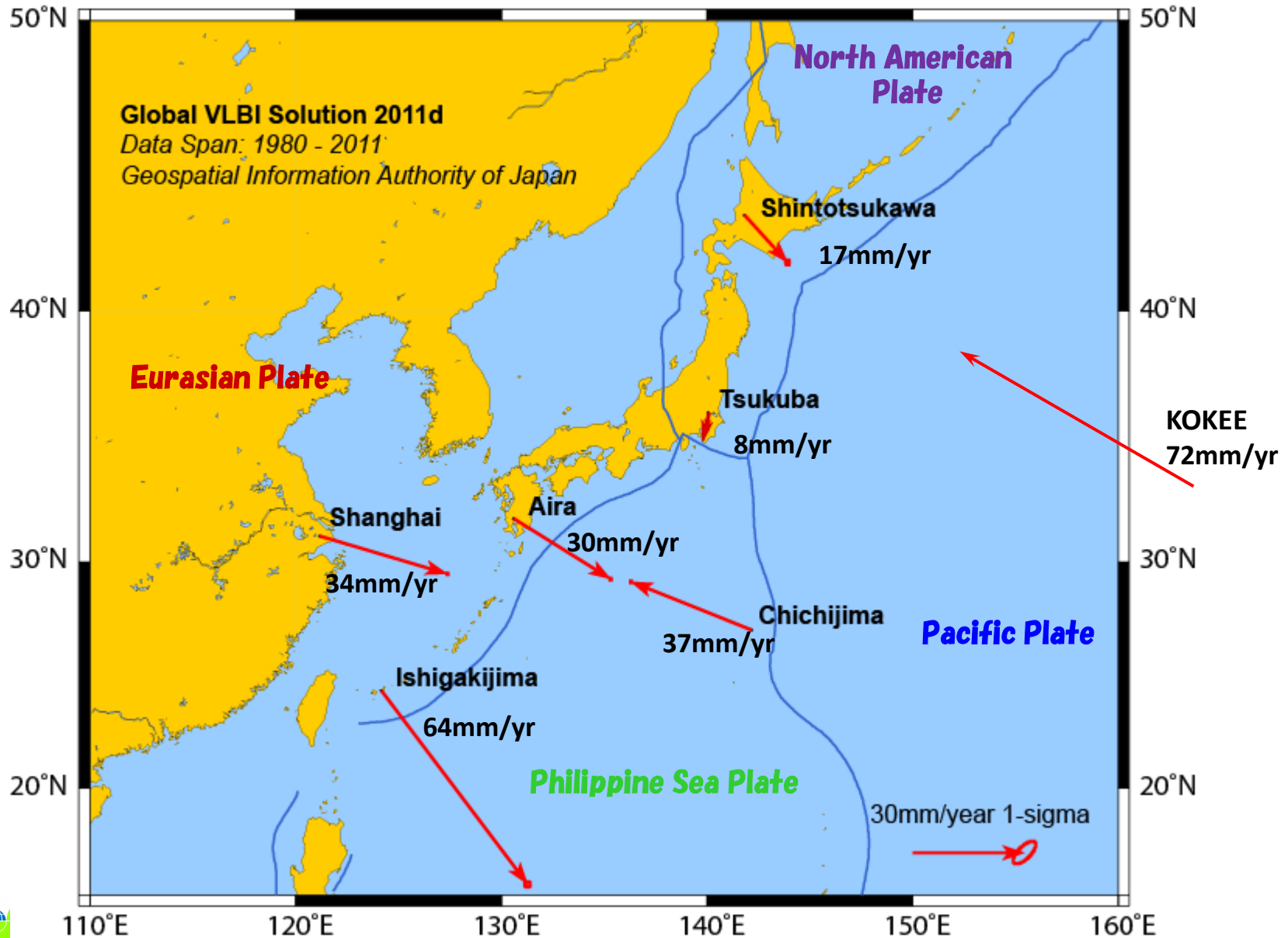
**Aira 10m**

**Chichijima 10m**

IVS-T2  
APSG  
JADE



# VLBI velocities around Japan before March 11, 2011



# Past massive earthquakes in Japan

## Great Kanto Earthquake of September 1st, 1923



Collapsed Asakusa Ryo-Un Kaku

September 1<sup>st</sup> 1923, the earthquake which hit south area of Kanto region caused serious damage, such as 105,385 missing and dead, 109,713 completely collapsed houses, 212,353 completely burned houses. It is said that total amount of damage reached one year and 4 month's amount of national budget at the time.



Black smoke of central Tokyo on the afternoon of September 1st

# Past massive earthquakes in Japan

Hanshin-Awaji Earthquake of January 17th, 1995 (05:46 a.m.)



Burned building  
in Nagata-ku,  
Kobe city

Collapsed Hanshin  
expressway in Kobe  
city



# 2011 off the Pacific coast of Tohoku Earthquake

## Summary

Date: March 11, 2011

Time: 14:46 (JST)

Epicenter: 130 km ESE from Oshika Peninsula

Depth: 24km

Magnitude: 7.9 -> 8.4 -> Mw 9.0 (JMA)

Aftershocks: 6 of M7.0<, 96 of M6.0<,  
588 of M5.0< (as of Feb 8, 2012)

Tsunami:

9.3 m at Soma Tidal gauge station (JMA)

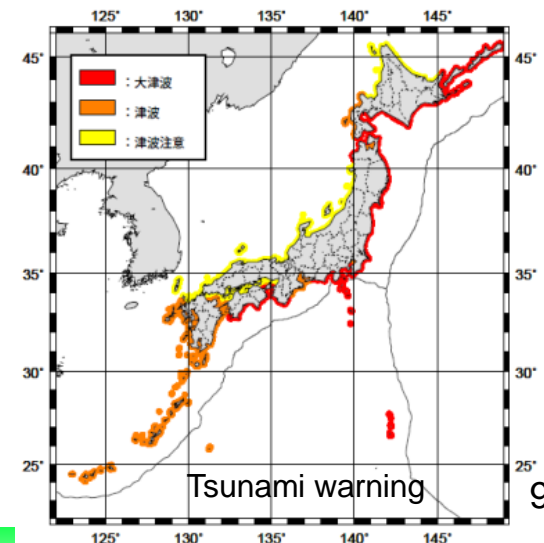
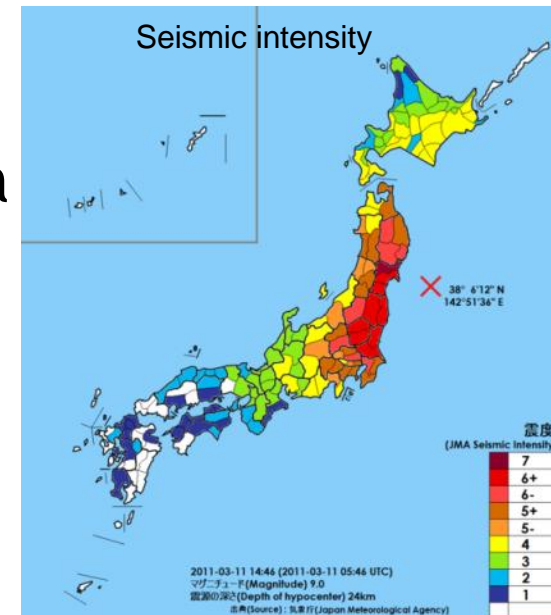
Max. run-up height over 40 m at Miyako

Damages (as of Feb 21, 2012)

15,852 people killed, 3,287 missing

Fully-destroyed buildings: 128,716

Partially-destroyed buildings: 244,991



# Location of Tsukuba & Kashima



# Location of Tsukuba & Kashima



# Damages around Tsukuba



Shopping center near my home

- JMA seismic intensity scale: lower 6 (3<sup>rd</sup>-highest level of 0-7 scale)
- Electricity: 2 day's blackout
- Water: 3 day's water supply interrupted

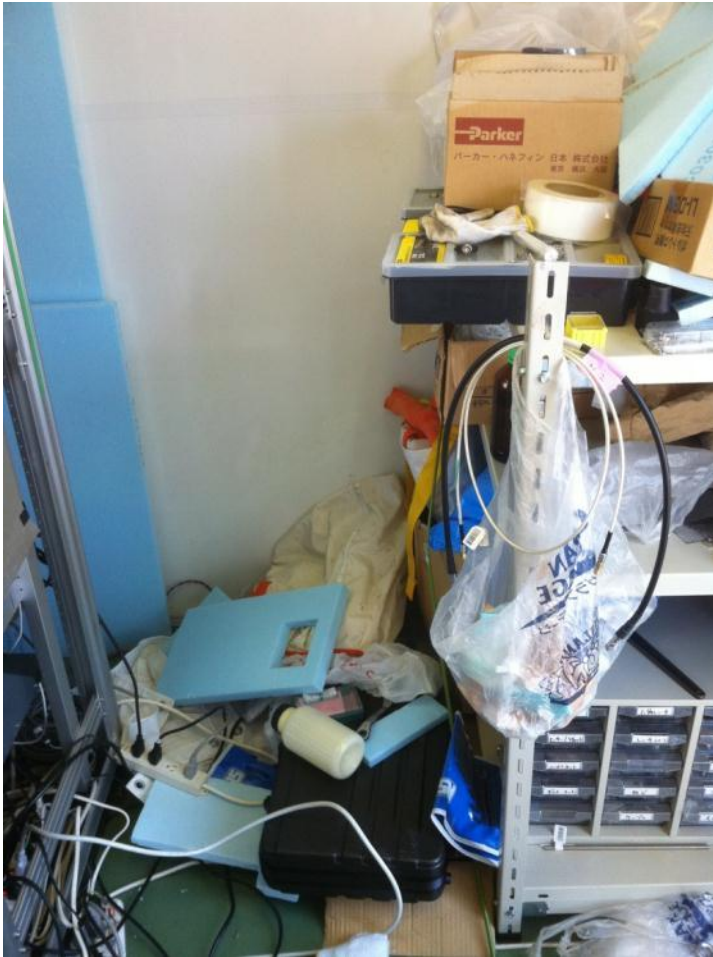


Gymnasium of my son's primary school; the wall fell down

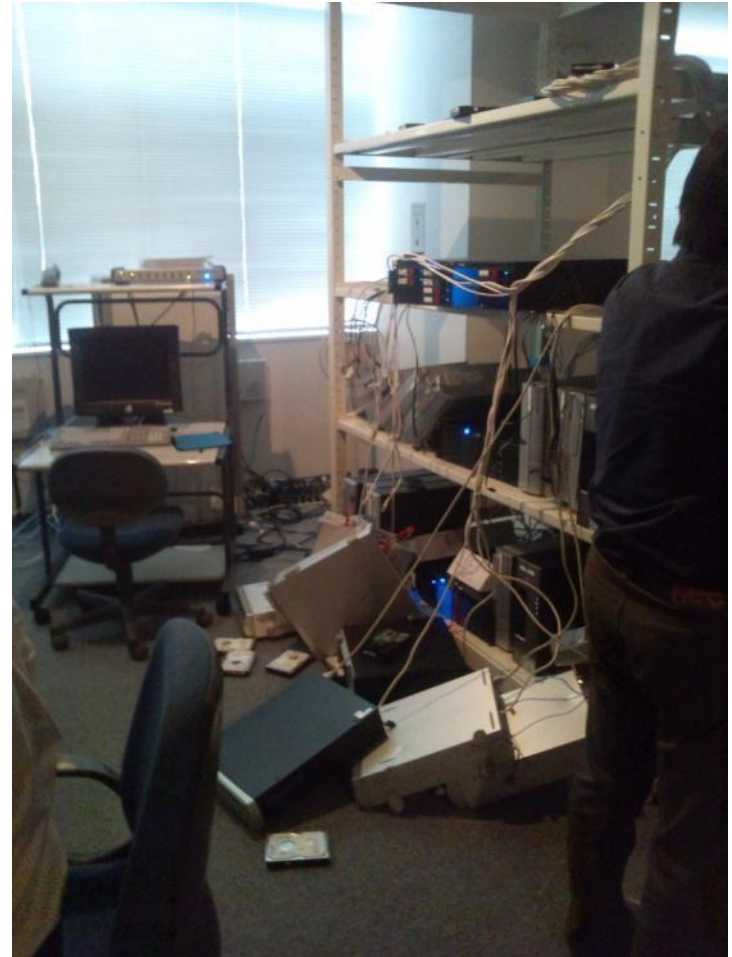


Closed road due to cracks near my home

# Tsukuba station and Correlator



messy K-band receiver room



Some of computers fell down from rack, and broke.

# Tsukuba 32-m antenna after Earthquake



- The large elevation gear shaking from side to side.
- But miraculously, there is no critical damage in the antenna.
- Since we were afraid of damage due to large aftershocks, we postponed restarting of operation.
- Additionally we found broken electric relay for Az drive controller (not due to the earthquake). 2 weeks to replace.



# Serious damages around Kashima



above left: Tsunami 2.6 km away from NICT



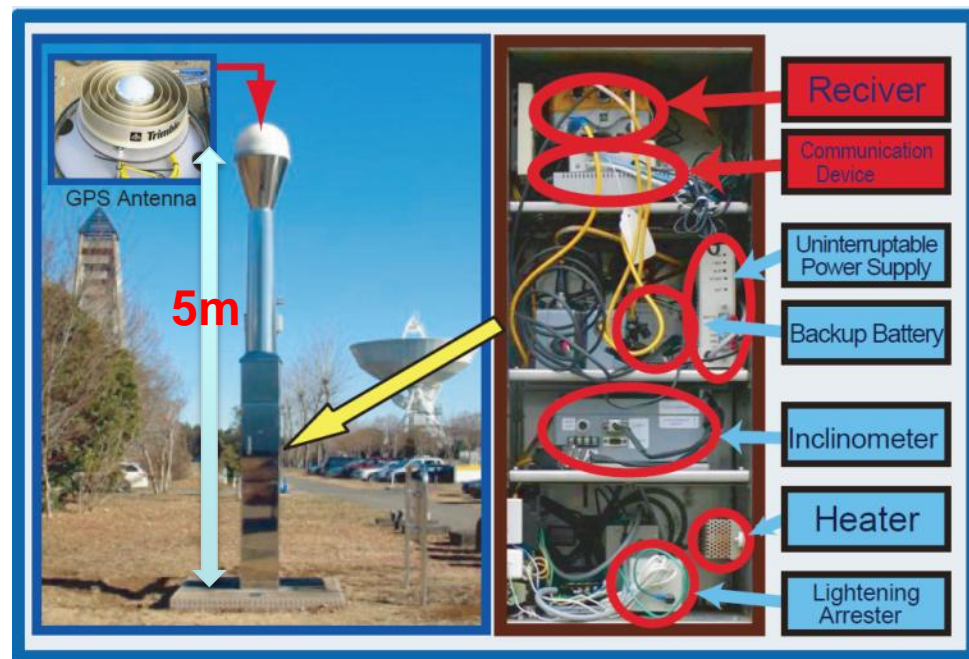
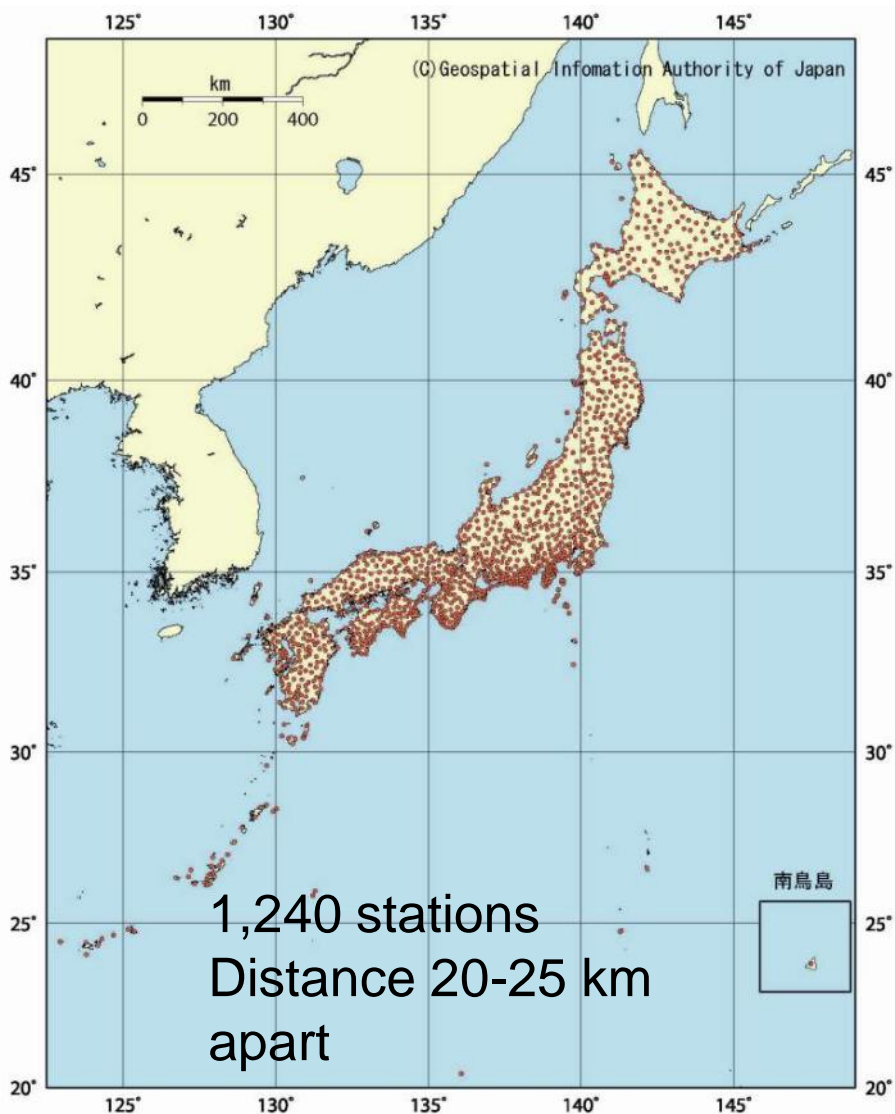
above right: twisted railway 0.45 km away from NICT

right: badly cracked road near NICT



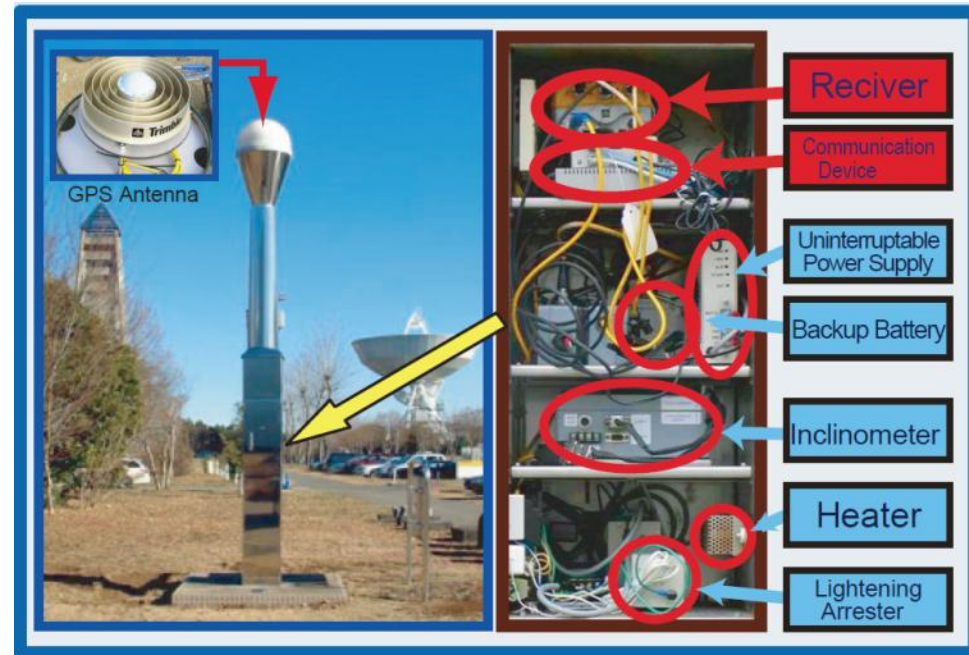
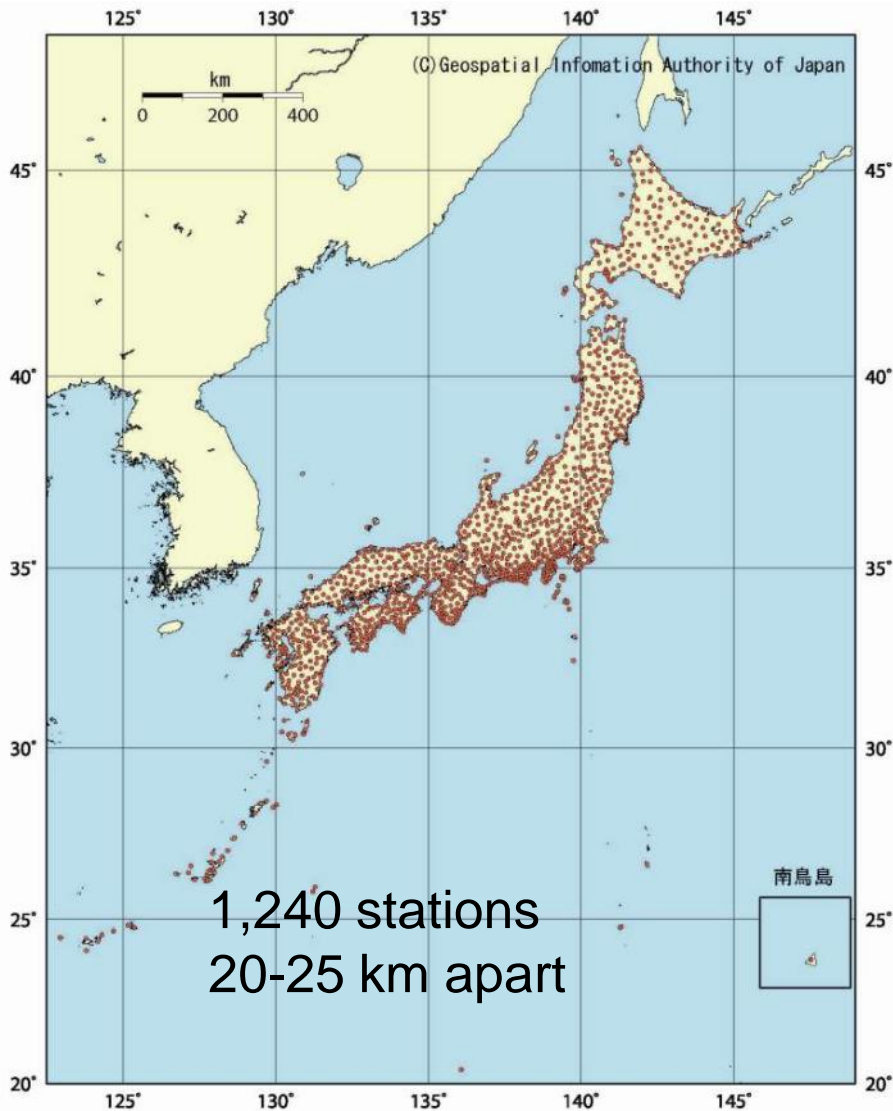
The detail was reported on poster 5.51.  
(Ichikawa, R.)

# GEONET: GPS-based control stations



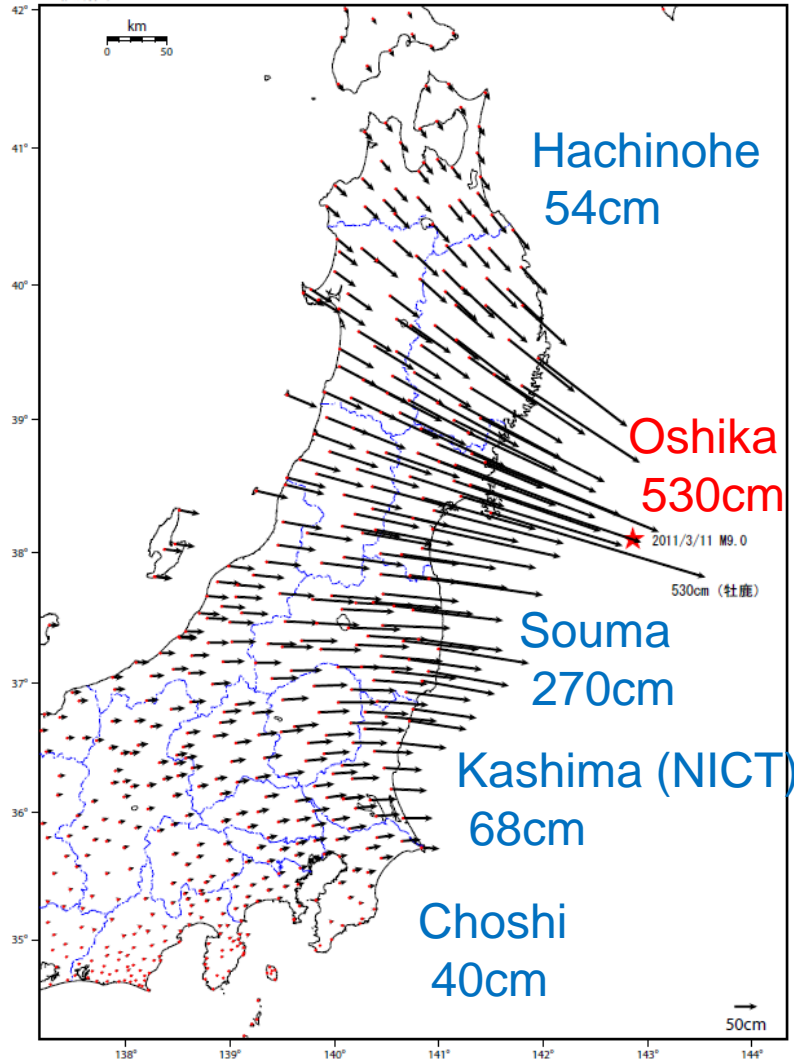


# GEONET: GPS-based control stations



# Co-seismic displacement detected by GEONET

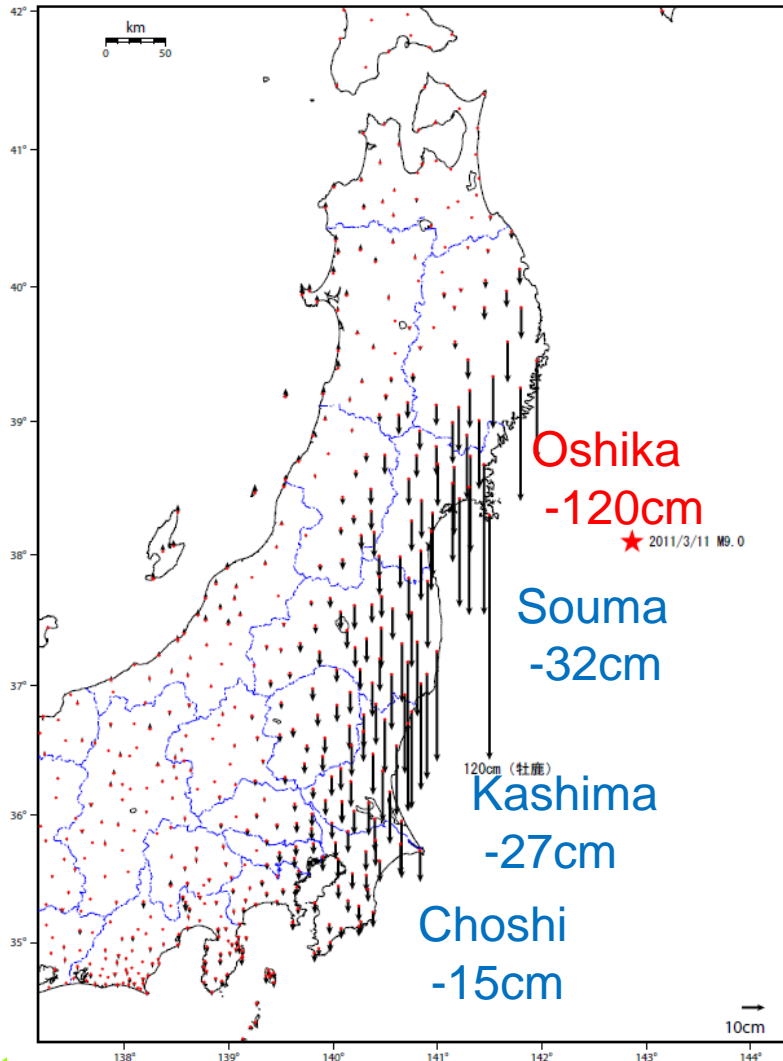
## Horizontal 5 hours after the main shock



- co-seismic horizontal displacement for 5 hours after the main shock
- main shock, some aftershocks and post-seismic displacement within 5-hr is included.
- Max. displacement is Oshika, 5.3m which is largest displacement ever.
- The direction of the displacement is southeast in Tohoku and east in Kanto.

# Co-seismic displacement detected by GEONET

## Vertical 5 hours after the main shock

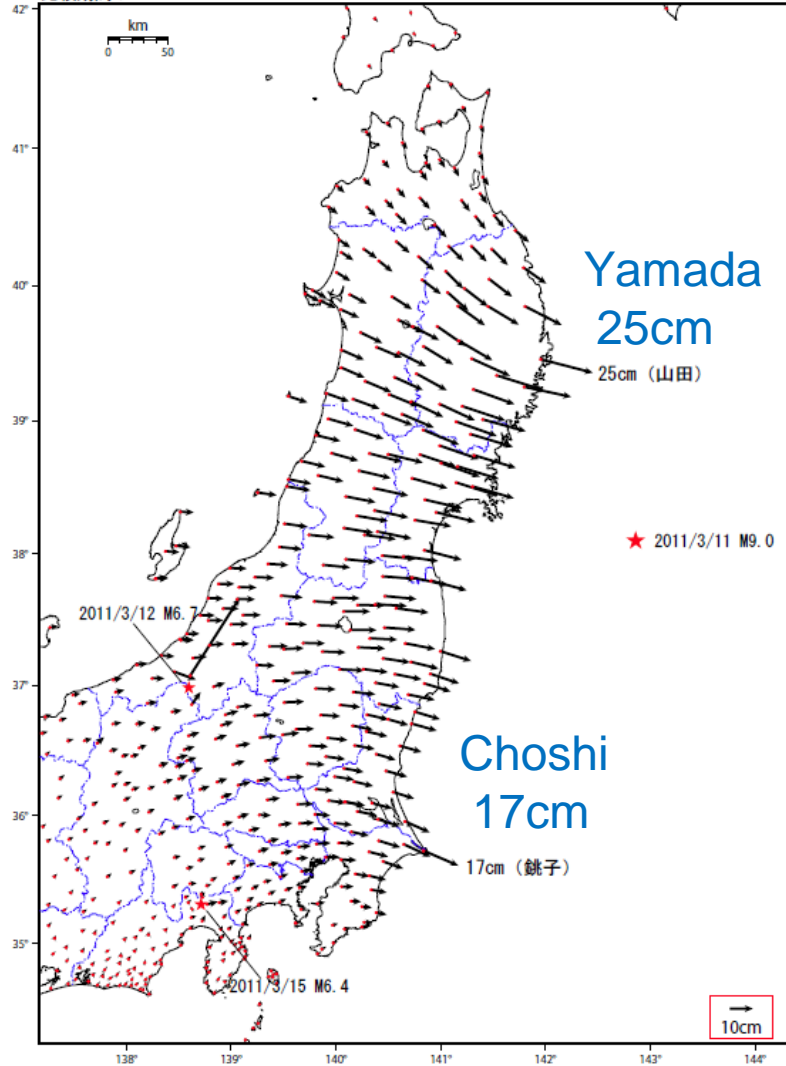


- co-seismic vertical displacement for 5 hours after the main shock
- main shock, some aftershocks and post-seismic displacement within 5-hr is included.
- Almost all points were subsided.
- Max. subsidence is Oshika, -1.2m.

# Post-seismic displacement detected by GEONET

## Horizontal

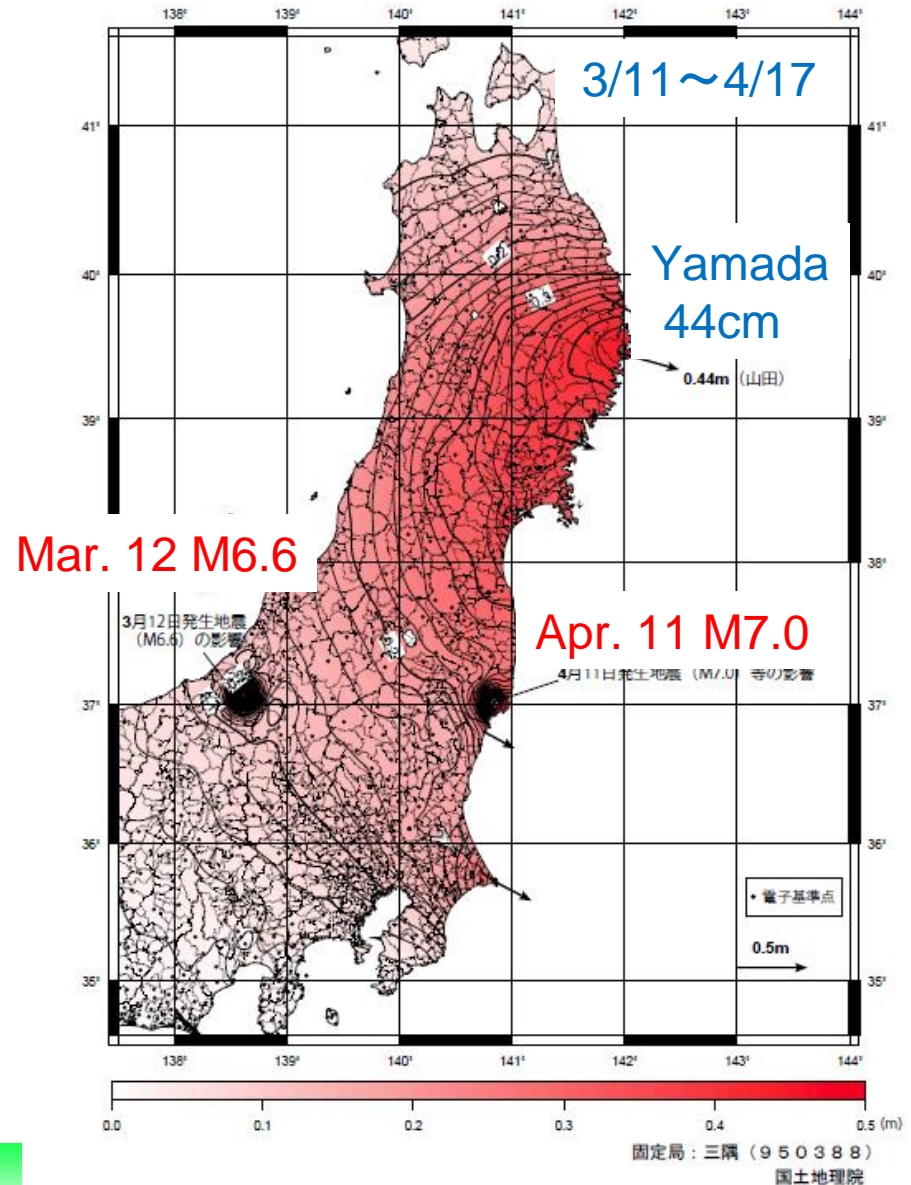
基準期間：2011/03/11 18:00 - 2011/03/11 21:00  
 比較期間：2011/03/19 00:00 - 2011/03/19 03:00 3/11~3/19



[Q3迅速解]

★固定局：三隅 (950388)  
 国土地理院

3月11日の本震直後から4月17日までの地殻の動き(水平方向)を電子基準点の観測結果をもとに、等変動量線で表示したものです。



Mar. 12 M6.6

Apr. 11 M7.0

固定局：三隅 (950388)  
 国土地理院

# Restarted IVS Observation

MARCH - APRIL, 2011

SUN	MON	TUE	WED	THU	FRI	SAT
6	7	8	9	10	<b>11</b>	12
INT	INT	R1473				
13	14	15	16	17	18	19
			R1474			
20	21	22	23	24	25	26
	R1475	T2075				
27	28	29	30	31	1	2
	R1476	RD1102				
3	4	5	6	7	8	9
	R1477	RDV86				
10	11	12	13	14	15	16
	R1478	JD1104	RD1103			

25 days after the earthquake

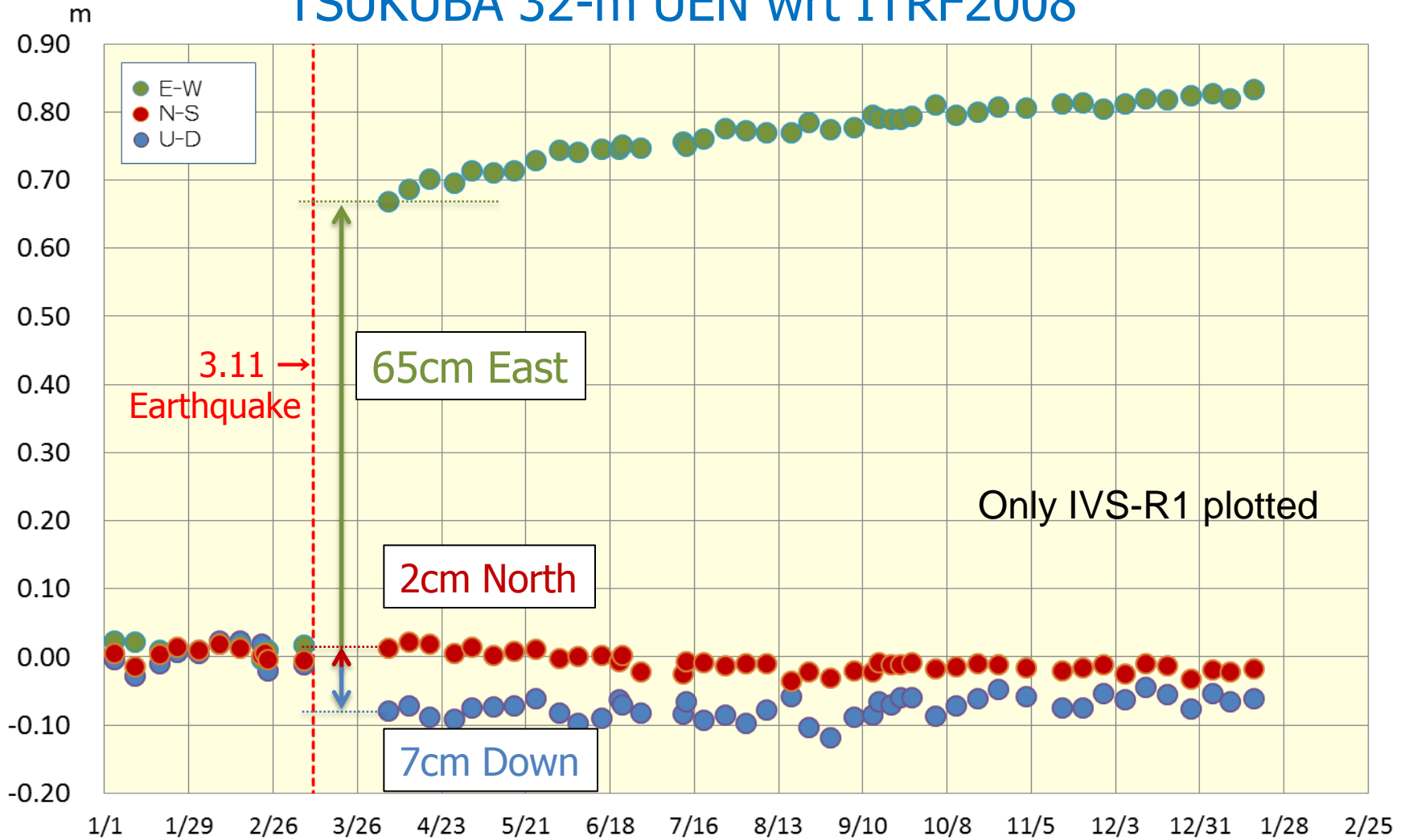
 canceled

 observed

Intensive was restarted on May 7

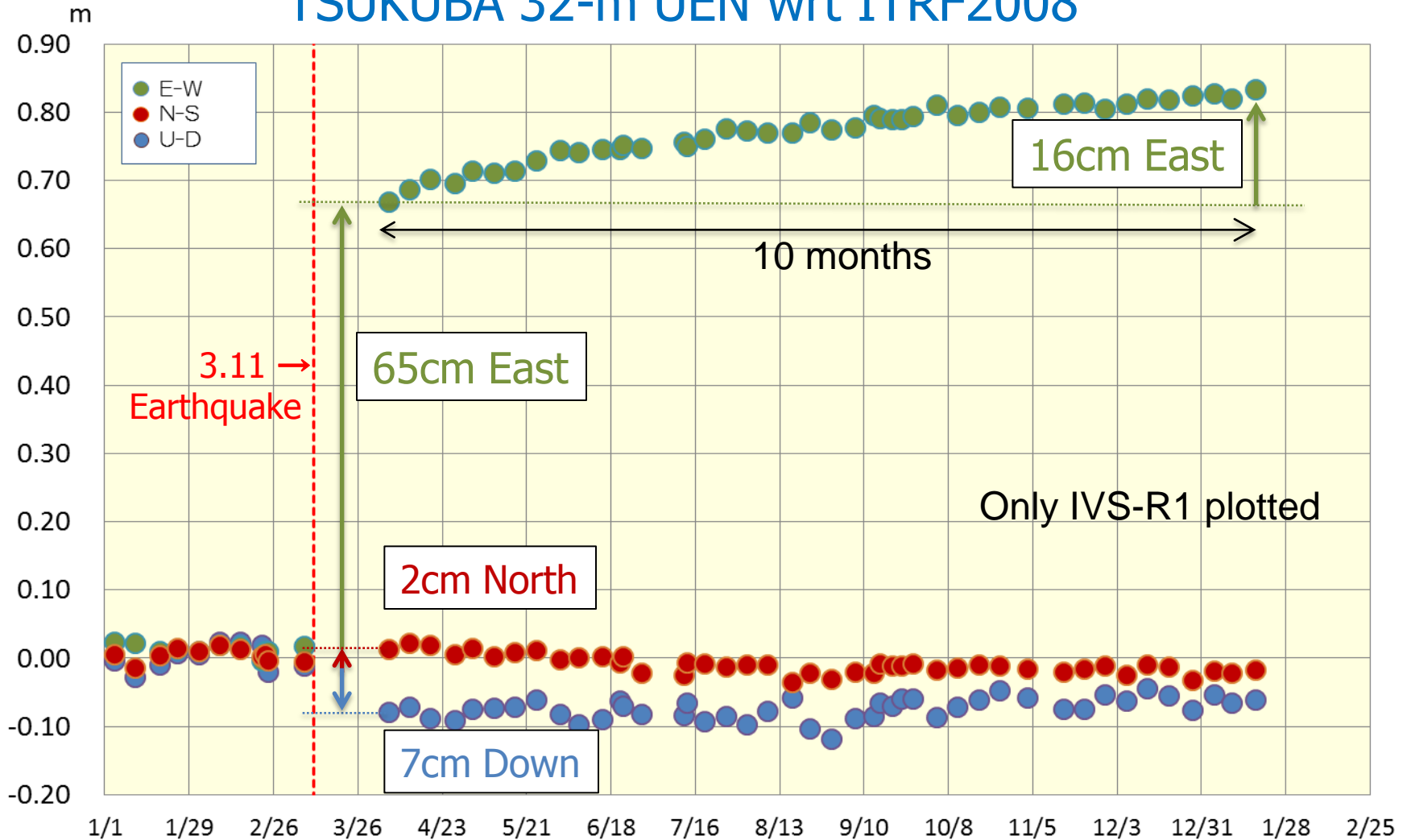
# VLBI positions before and after the earthquake

## TSUKUBA 32-m UEN wrt ITRF2008



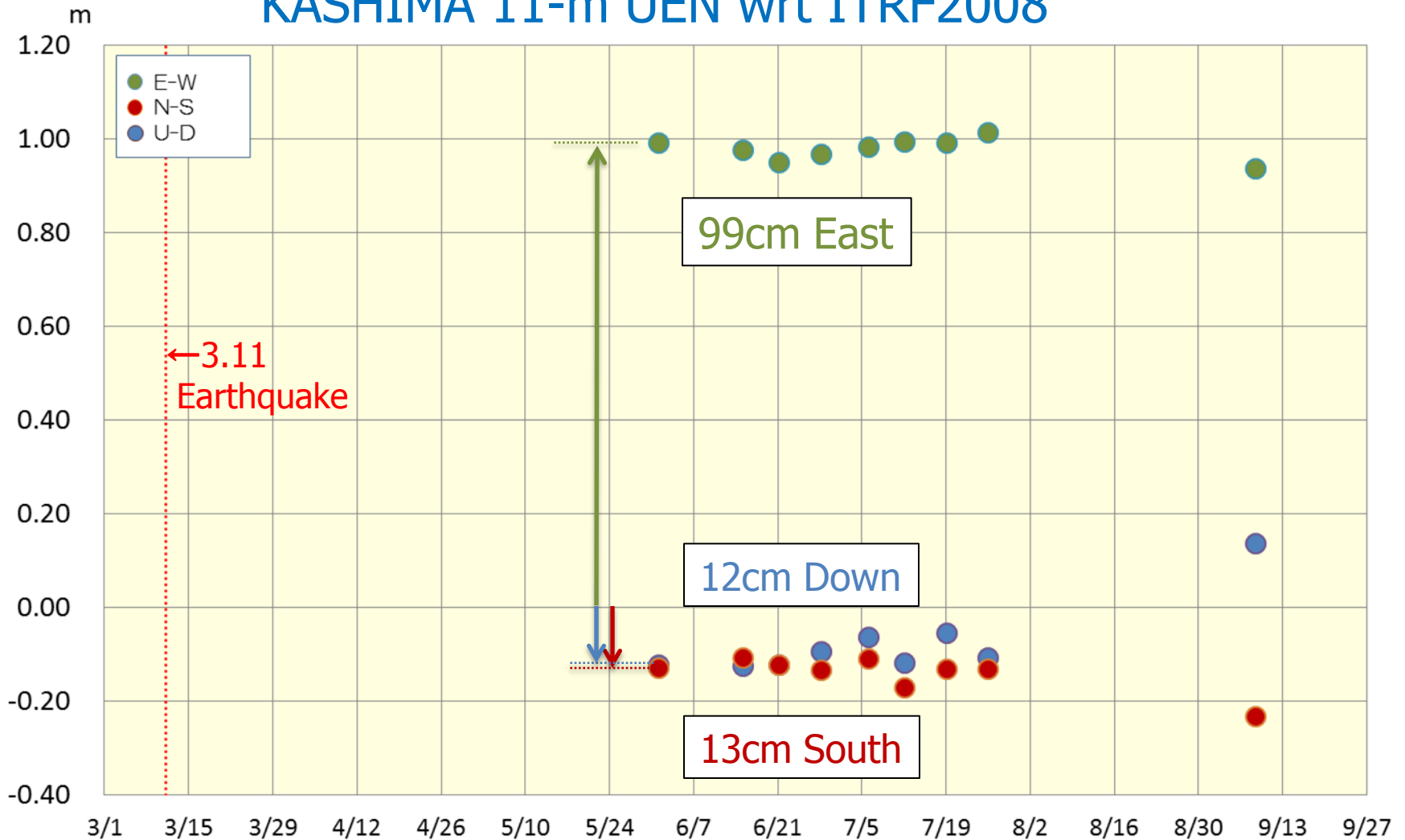
# VLBI positions before and after the earthquake

## TSUKUBA 32-m UEN wrt ITRF2008



# VLBI positions after the earthquake

## KASHIMA 11-m UEN wrt ITRF2008





# Survey results of control points

## Infrastructure for administration of country

- Maintaining control points (GEONET, triangulation points, benchmarks)
- Publishing survey results (lat., lon., height) for public survey of local government



GPS



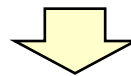
Triangulation point



Benchmark

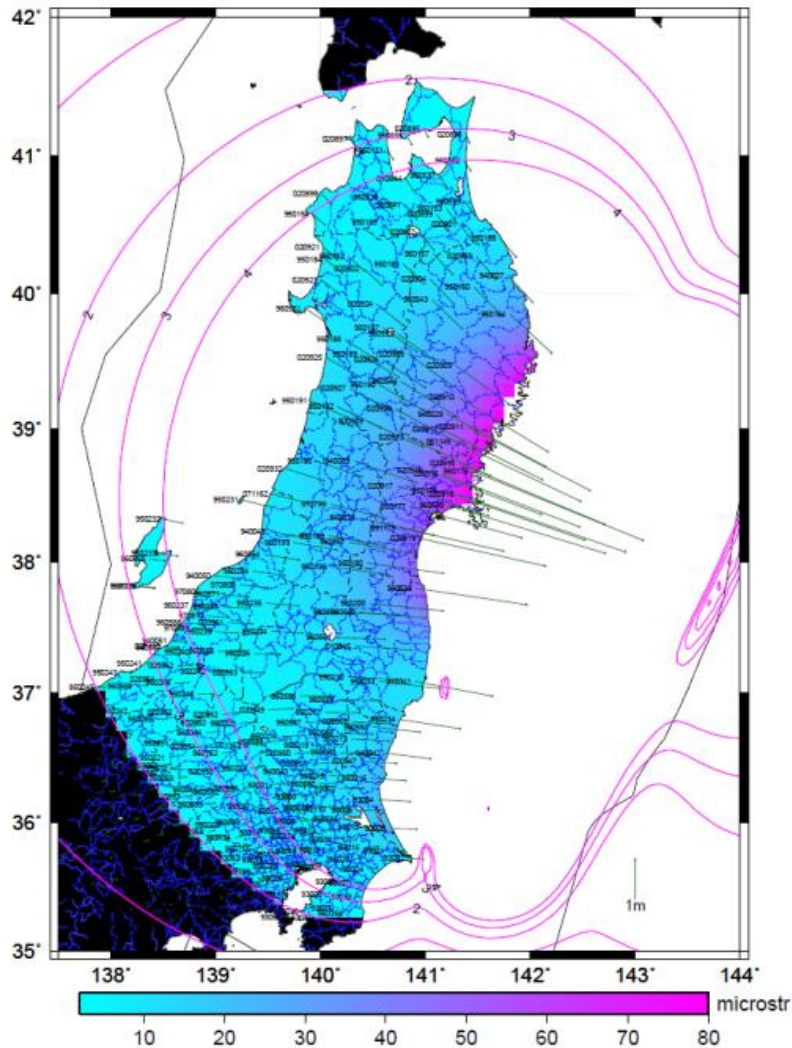
## ◇ Survey Act, Article 31 (revision of survey result)

The Director-General of Geospatial Information Authority of Japan shall revise the survey result without delay, in the case where the survey result of basic survey is not in conformity with the current status due to the change of the geosphere, the topography or the feature, or other reasons.



**GSI is responsible for revising coordinates of control points immediately in case where the position was changed.**

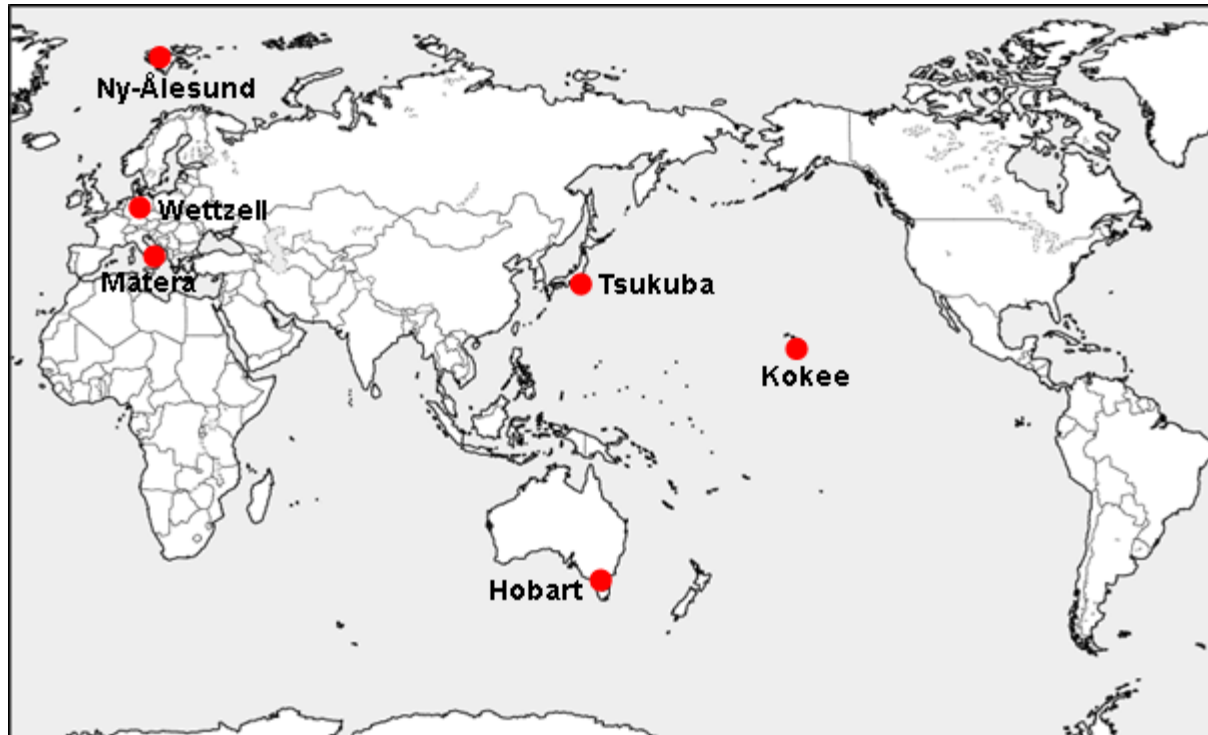
# Interrupt publishing survey results of control points



Area the distortion becomes over 2 ppm

- the crustal displacement was widespread and its magnitude was very large.
- GSI determined the revision area where the distortion becomes over 2 ppm.
- the area covered the eastern half of Japan; 20 prefectures.
- GSI interrupted to publish the survey result immediately after March 11.

# VLBI position as practical origin of control points



IVS -R1482 on May 9-10

VLBI position

TSUKUB32

epoch: May 10, 04:58:26

X= -3957409.226 m

Y= 3310228.897 m

Z= 3737494.719 m

Analysis strategy:

- A priori station: ITRF2008 (pos & vel)
- A priori source: ICRF2
- Strong constraint NNT/NNR except TSUKUB32
- independent solution of Calc/Solve



# Procedure for calculating coordinates of control points



TSKB IGS station  
epoch May 10

Colocation vector  
from VLBI to TSKB  
(  $\Delta X$ ,  $\Delta Y$ ,  $\Delta Z$  )



X, Y, Z, epoch May 10



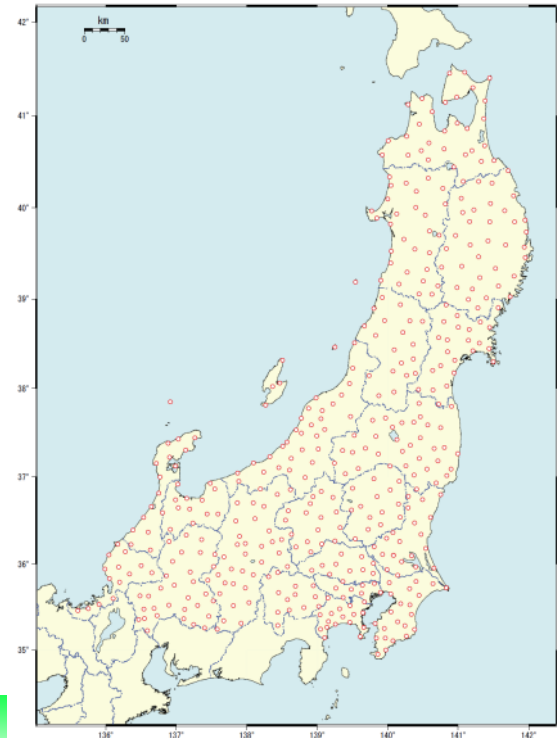
Add postseismic displacement  
for 2 weeks detected by GEONET

TSKB IGS station  
epoch May 24



**438** points of GEONET station  
coordinates were calculated by  
TSKB coordinate as given  
coordinate.

**First, the GEONET coord. were published  
on May 31.**



# New survey result was published

	# of points
GPS-based control stations	438 / 1,240
Triangulation points	43,857 / 109,074
1 <sup>st</sup> -order	353 / 975
2 <sup>nd</sup> -order	2,140 / 5,060
3 <sup>rd</sup> -order	15,170 / 32,326
4 <sup>th</sup> -order	26,194 / 70,713
Benchmarks	1,379 / 18,239
Total:	45,674 / 128,553 ( <u>35.3%</u> )



published on October 31

About 2,000 of control points were resurveyed and others were calculated by adjustment parameter.

# Summary

- The Tohoku mega earthquake and great tsunami caused by the earthquake inflicted enormous damage on eastern Japan.
- Even in Ibaraki prefecture where GSI and NICT are located, a lot of roads and buildings were damaged.
- GSI observed larger displacement than ever before by using space geodetic techniques, the results became well-known throughout the world.
- Furthermore, the post-earthquake position of Tsukuba VLBI station became the practical origin of revised control points which is 35 % of whole control points in Japan.
- Even now, just one year later, post-seismic displacement has lasted and an aftershock occurs at least a few times a week even in Tsukuba.

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- Even now, just one year later, post-seismic displacement has lasted and an aftershock occurs at least a few times a week even in Tsukuba.
- **The greatest impact for us is that the budget for VLBI2010 was approved as a budget for disaster, due to the Tohoku earthquake.**

Thank you for your attention.

