

FIG Working Week 2012
May 7, 2012, Rome

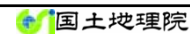
Revision of the results of control points after the 2011 off the Pacific coast of Tohoku Earthquake



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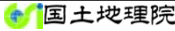
1. Geodetic control point network in Japan

2. Crustal deformation observed by GEONET

3. Revision of the results of control points




- Origins of the Japanese horizontal / vertical control networks
- GNSS-based control stations
- Triangulation stations and bench marks

4. Summary

1. Geodetic control point network in Japan 

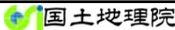
Control Points in Japan (maintained by GSI)

to provide the reference positions for Basic Survey and Public Survey

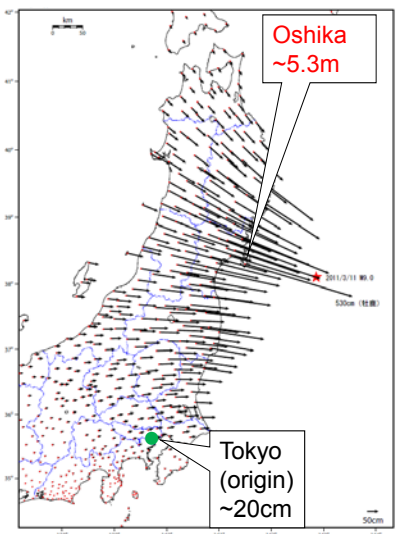
Category	# of stations	Sub-category	Average Interval
GNSS-based control stations (GEONET) 	1,240		20 km
Triangulation stations 	109,074	First order triangulation stations 975	25 km
		Second order triangulation stations 5,060	8 km
		Third order triangulation stations 32,326	4 km
		Fourth order triangulation stations 70,713	1.5 km
Bench marks 	18,239	Fundamental bench marks 86	150km
		First order bench marks 14,682	2 km
		Second order bench marks 3,471	2 km
Total	128,553		

(as of March 31, 2011)

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2. Crustal deformation observed by GEONET 

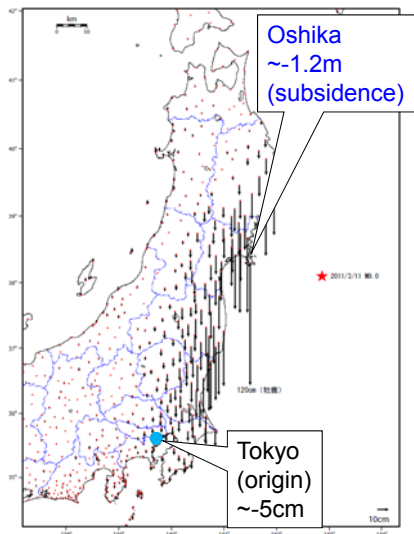
Horizontal



Oshika
~5.3m

Tokyo
(origin)
~20cm

Vertical



Oshika
~1.2m
(subsidence)

Tokyo
(origin)
~5cm

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3. Revision of survey data

There were two important points to be considered

◇When, and where

should we revise the survey data?

to meet two different requests simultaneously;

A: "As soon as possible" for quick recovery

B: "Stand by" to avoid further revision due to after slip

Conflicting!

◇How much error

can we allow?

Criterion: error within ~2ppm between neighboring stations

The criterion meets the Regulation of Public Survey Specification in Japan

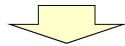
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Estimation of amount of after slip

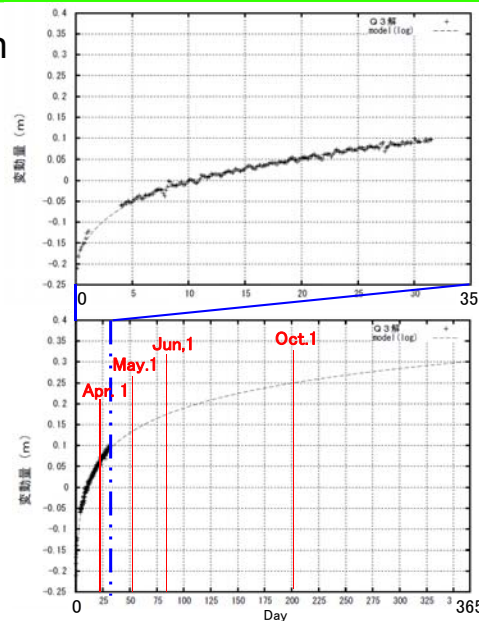
Logarithmic model function is adopted to estimate the future trend of after slip.

$$y(t) = c + a \ln \left(1 + \frac{t}{\tau_{\log}} \right)$$

(c, a: constant, τ_{\log} : constant(time), t: time)



→ We decided that the survey data should be revised in the end of May, considering the future amount of strain.




Estimated after slip at the site "Yamada" (#950167)


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Amendment of ordinance on origins of control network

Origins of horizontal / vertical control network moved due to Tohoku Earthquake:
eastward by ~20cm (horizontal), downward by ~5cm (vertical)



• Origin of Horizontal Control Network
for geographical latitude and longitude



• Origin of Vertical Control Network
for height


Order for Enforcement of the Survey Act was revised and enforced on October 21, 2011.

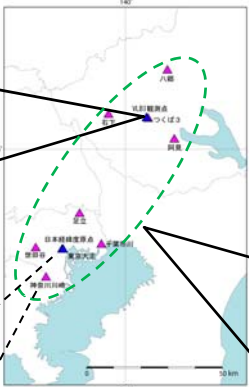
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Procedure of revision (horizontal origin)

1. Determine the coordinate of VLBI station "Tsukuba" as of May 24, 2011.







2. GPS observation* was carried out around VLBI station "Tsukuba" and the Origin, respectively.



The metal marker of the Origin



GNSS-based control station



(Marked as ▲)

3. The coordinates of the stations were calculated under the condition that the coordinate of VLBI station "Tsukuba" is fixed.


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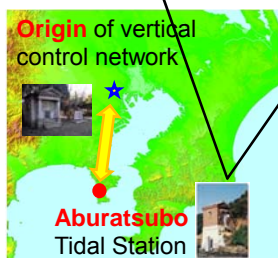
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Procedure of revision (vertical origin)

We have kept tidal observation at Aburatsubo Tidal Station since 1894. And...

- There's no long-term trend in sea level.
- No significant vertical displacement by Tohoku Earthquake at "Aburatsubo" according to GPS observation results.





Origin of vertical control network

Aburatsubo Tidal Station

Leveling from Aburatsubo to the Origin was carried out, and the height of the Origin was calculated under the condition that;

- (1) No long-term change in sea level
- (2) No vertical co-seismic displacement at "Aburatsubo"

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Revision of survey data (GNSS-based control stations)

East Japan

Survey data were closed (Mar. 14)

↓

GPS & VLBI observations & analyses.

↓

Poor precision around the border of revised / non-revised area.

↓

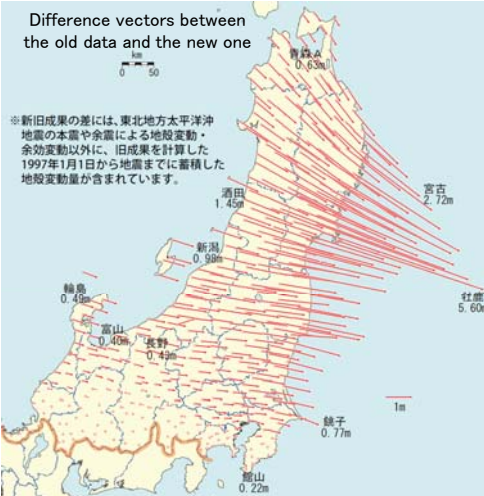
Revising area was extended

↓

New survey data were opened (May. 31)

West Japan & Hokkaido

Not revised

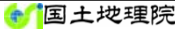


Difference vectors between the old data and the new one


※新旧成果の差には、東北地方太平洋沖地震の本震や余震による地殻変動・余効変動以外に、旧成果を計算した1997年1月1日から地震までに蓄積した地殻変動量が含まれています。

All data set is called "Geodetic Coordinates 2011"


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Procedure of revision (Triangulation stations) 

- It was impossible to operate observations at ~44,000 suspended triangulation stations.
→ How to revise all data?

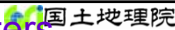


- GNSS observations at about 600 selected stations
- Correction parameters were calculated using the results of observation.
- Adapt the parameters to other non-observed triangulation stations.
- Check the results by supplementary GNSS observation.

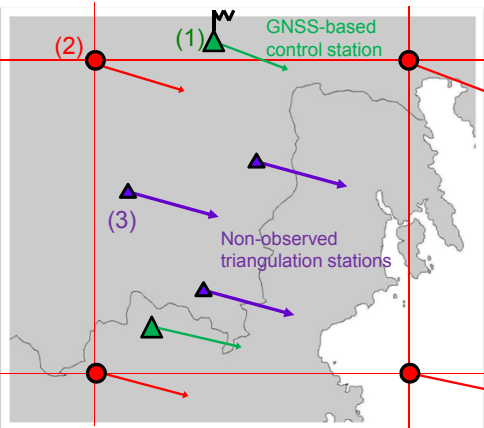


600 "high order control points" in Tohoku - Kanto, Koshin, etsu areas

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Generation & Adaptation of correction parameters 

(1) GNSS observation at the selected stations
 (2) Each corner of 1km grid is given correction parameters
 (3) The correction vector of the station is interpolated



- : Grid point having parameters
- : Known displacement of the station
- : Correction vector at the grid point
- : Interpolated correction vector

Correction image

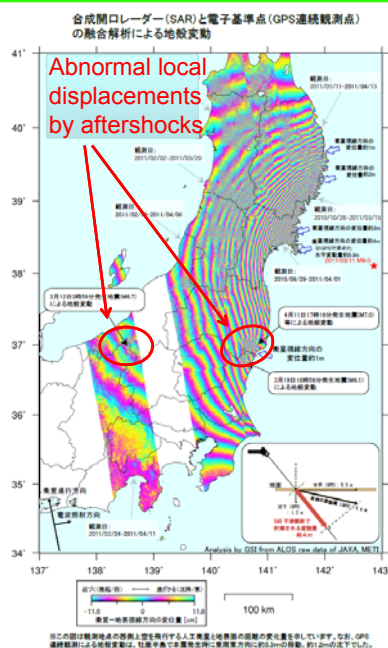
Before the EQ	+	Correction	=	After the EQ
X=1234. 00m		X=-0. 10m		X=1233. 90m
Y=7890. 00m		Y=+0. 50m		Y=7890. 50m

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Exception of correction parameters' adaptation 国土地理院

Some areas have been suffered from aftershocks (or induced earthquakes) since Mar. 11.

We checked the areas with SAR interferometry where the correction parameters should not be adapted.



Tools for revision with correction parameters 国土地理院

GSI is providing following tools to revise survey results

- Software "PatchJGD"
- Correction parameter files



PatchJGD (Main display)



Download site at GSI's HP.

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Revision of survey data (bench marks)


Leveling at ~1900 1st order bench marks (along ~3600km leveling route) in East Japan

↓

Net adjustment fixed to the multiple bench marks and the Origin revised.

↓

New survey data were published. (Oct. 31)



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4. Revision of survey data (Summarized chronology)

	"Initial Action" phase				"Recovery & Reconstruction" phase	
	3hours	2days	3days	1week	1month	6month
GEONET (GNSS-based control stations)	Mar. 11 Flash report (quick results)	Observation of after slip			May. 31 Revision of survey data (GNSS-based control stations)	234 days after the EQ
Triangulation stations & bench marks				Re-survey (Origins)	Re-survey (triangulation stations & bench marks)	Oct. 31 Revision of survey data (triangulation stations & bench marks)
Ordinance (coordinates of origins)				Government's hearing & consultation		Oct. 21 Cabinet council meeting Enforcement of ordinance

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(Appendix) Recent revisions of survey data due to earthquakes

Earthquake	Horizontal Displacement & Data suspension	Time Schedule
Sep. 26, 2003 Off-Tokachi	87cm No suspension of data provision	<p>Jun. 1, 2004 Survey data of GNSS-based control stations were revised</p> <p>Maximum after slip of the stations became shorter than 1cm/month</p> <p>Re-survey at 196 triangulation stations</p> <p>Correction parameters (PatchJGD) → Re-calculation →</p> <p>Apr. 1, 2005 6,700 data are completely revised</p>
Oct. 23, 2004 Niigata-Chuetsu	20cm Survey data of 432 control points were closed	<p>Nov. 19, 2004 New survey data of GNSS-based control stations were opened</p> <p>Re-survey at 608 triangulation stations</p> <p>Dec. 28, 2004 90 data were precedently opened</p> <p>Dec. 22, 2005 600 data are completely revised</p>
Jun. 14, 2008 Inland Iwate-Miyagi	150cm Survey data of 2,631 control points were closed	<p>Aug. 4, 2008 New survey data of GNSS-based control stations were opened</p> <p>Re-survey at 285 triangulation stations</p> <p>Correction parameters (PatchJGD)* *Not applicable for some area</p> <p>Re-calculation →</p> <p>Mar. 2, 2009 2,300 data are completely revised</p>
Mar. 11, 2011 Off-Tohoku	530cm Survey data of 44,000 control points were closed	<p>May 31, 2011 New survey data of GNSS-based control stations were opened</p> <p>Re-survey at 1,900 triangulation stations</p> <p>Re-survey of bench marks along 3,600km leveling route</p> <p>Oct. – Nov., 2011 All survey data are revised</p>

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