The new application of GEONET for multi-GNSS observation and height determination with new Japanese geoid model

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Outline

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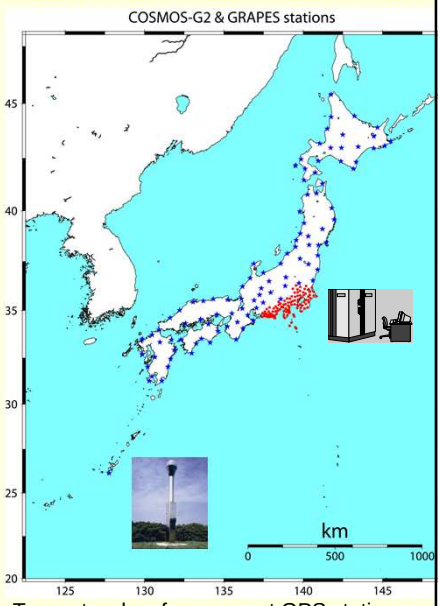
GEONET & its brief history

<Beginning: two CORS networks>
dual-frequency GPS observation stations
5m-tall pillar with 2m-depth ground base
Central control station at Tsukuba h.q.

・April 1, 1994 : dots in red
intensive monitoring of crustal deformation
110 stations at average spacing of 15 km
in metropolitan area & anticipated area of large earthquake occurrence

・October 1, 1994 : dots in blue
Nationwide network of CORS
100 stations at average spacing of 120 km
Geodetic reference & crustal deformation monitoring



Two networks of permanent GPS stations

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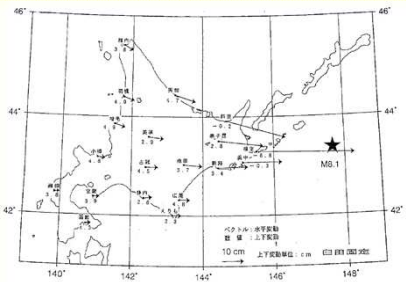
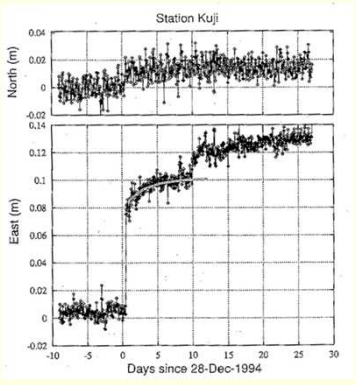
GEONET & its brief history (cont.)

co- seismic crustal deformation
Oct 4, 1994, east off Hokkaido Eq.(M8.1)
Oct 6 preliminary results reported in two days
max: 44 cm east/ 10 cm down at Nemuro



Horizontal coseismic displacement vectors
1994 East Off Hokkaido Earthquake (M8.1)



Time series of baseline components
1994 Far Off Sanriku Earthquake (M7.5)

co- & post-seismic crustal deformation
Dec 28, 1994, far off Sanriku Eq.(M7.5)
post-seismic for 3 days: slow earthquake
for 60+ days: post-seismic deform

Powerful tool for monitoring & detecting crustal deformation
Contribution to understanding of crustal activities

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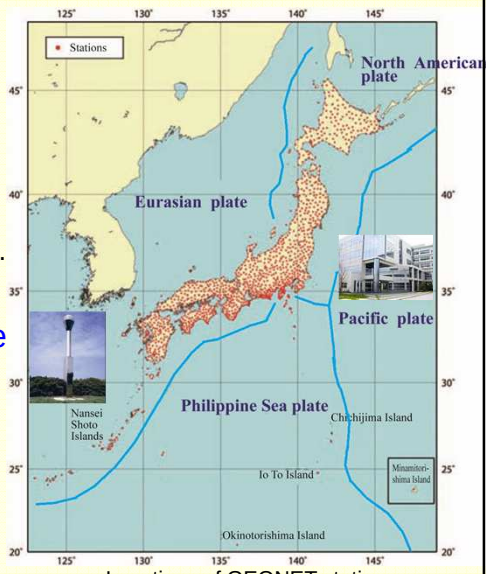
GEONET now: enhancement

GEONET : GNSS Earth Observation NETwork System

- Nationwide about 1,300 sites
  - at average spacing of 20km
  - multi-GNSS signal reception
- Real-time data at 1Hz sampling
  - Data provision via a distributer for network RTK & positioning service etc.
  - GPS, GLONASS, QZSS
- Data & position results available free of charge
  - Data at 30-second intervals
  - Operational precise coordinates (3 modes of analysis)



Locations of GEONET stations

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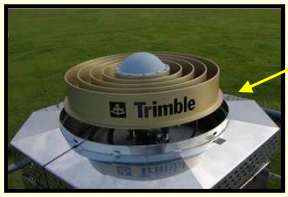
Specification of GEONET station

- Pillar : 5m Stainless steel Pillar
- Receiver : Trimble NetR9, TOPCON NET-G3 GPS, GLONASS, QZSS
- Antenna : Trimble Choke Ring (TRM59800.80),
  Topcon Choke Ring (TPS CR-G5) GPS, GLONASS, QZSS
- Data transport : IP-VPN for real-time + Mobile phone for emergency
- Battery : ~72 hour continuation
- Other : UPS, Heater, Fun, Power Monitoring, Lightning arrester, etc.



GNSS Choke-Ring antenna

GNSS Receiver and other devices (UPS, battery, communication device, etc.)

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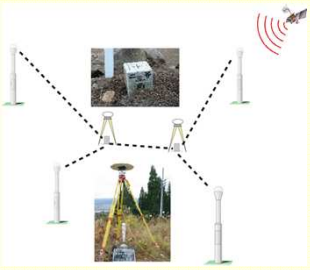
Roles as a national geodetic infrastructure

(1) Backbone of geodetic control stations

- CORS for survey: making triangulation points unnecessary
  1. For GNSS survey
     Providing coordinates at the antenna and 30s data without fees
  2. Ground survey such as TS survey and leveling
     Providing coordinates on the attached metal markers
- Effective updates of reference coordinates

(2) Support for real-time positioning (services) & weather forecast (GPS meteorology)

- RTK-GNSS positioning of aircrafts in aerial photogrammetry, airborne LiDAR survey, most effectively in emergency response



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Roles as a national geodetic infrastructure

(3) Global and regional geodetic reference frame

- development and maintenance of ITRF for global and APREF for regional geodetic reference frames

(4) Continuous monitoring of crustal deformation,

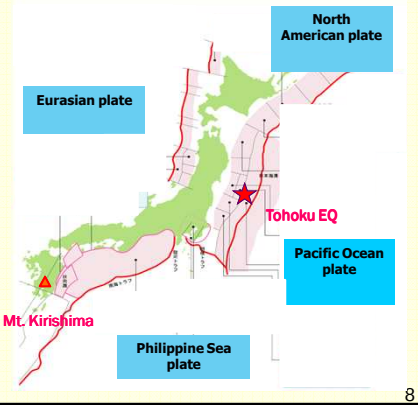
- understanding of earthquake occurrence/ volcanic activities
- contributions to emergency response/countermeasures to natural disasters
- fault slip inversion for supporting tsunami alert

e.g.1: 2011 Great Tohoku EQ

- 11/Mar/2011 05:46:23 UT
- 38.32N, 142.37N, 24km
- Mw=9.0
- Dead/Unknown : 21,176

e.g.2: 2011 Mt. Kirishima's Eruption

- 19/Jan/2011



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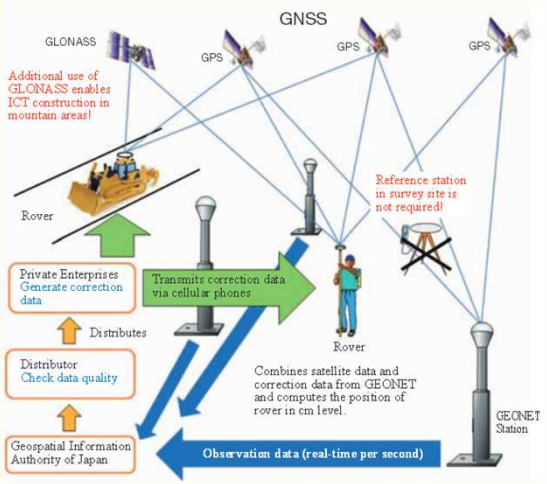
Support for real-time positioning (service)

- 1 Hz data of GEONET is provided to the end users in real-time by private companies through NPO distributors
- Main purpose of the service is
  - Network RTK for surveying
  - RTK positioning for photogrammetry, ICT construction
  - Location-Based services
- GLONASS and QZSS real time data are now available (from May 10, 2013) in addition to GPS



Schematic view of network RTK positioning with GEONET real-time data

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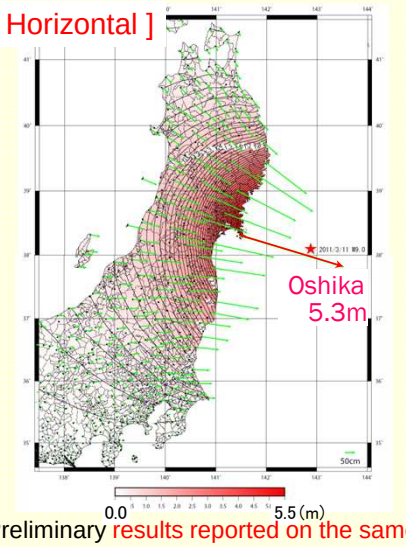
2011 Off the Pacific coast of Tohoku Earthquake

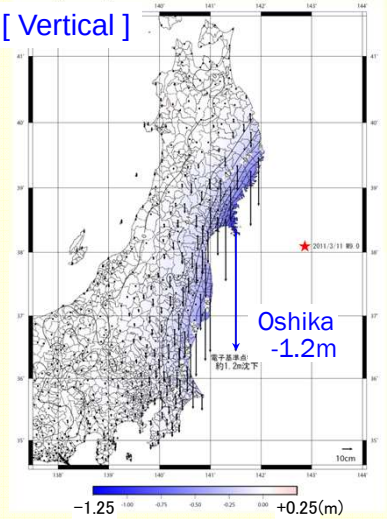
Co-seismic Movement

From: 1/Mar/2011 – 9/Mar/2011 JST
To: 11/Mar/2011 18:00 – 21:00 JST

[Horizontal]



[Vertical]



Preliminary results reported on the same day
Revised Coordinates of CORS stations: published on May 31, 2011
Those of other control points & bench marks: published on Oct 31, 2011

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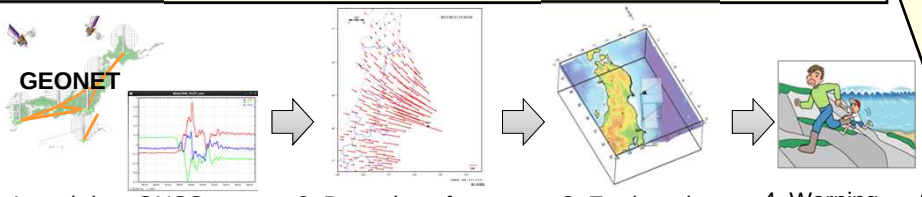
Real-time Analysis (Mw estimation system for tsunami alert)

REGARD (Real-time GEONET Analysis system for Rapid Deformation Monitoring)



1. real-time GNSS positioning
2. Detection of permanent displacements
3. Earthquake fault modeling
4. Warning *future plan

	1. GNSS positioning	2. Detection of permanent displacements	3. Estimation of fault model and Mw	4. Results
Methods	Always on (RTKLIB v2.4.1)	- "RAPiD" (Ohta et al., 2012) for automatic detection of permanent displacements - Triggered by Early Earthquake Warnings (JMA)	- Automatic estimation of single rectangular fault (Nishimura et al., 2010 (in Japanese))	- Notification message via E-mail - Expect contribution to TEW system Within 5 min.

*This project was launched in 2011 with the support of Tohoku University

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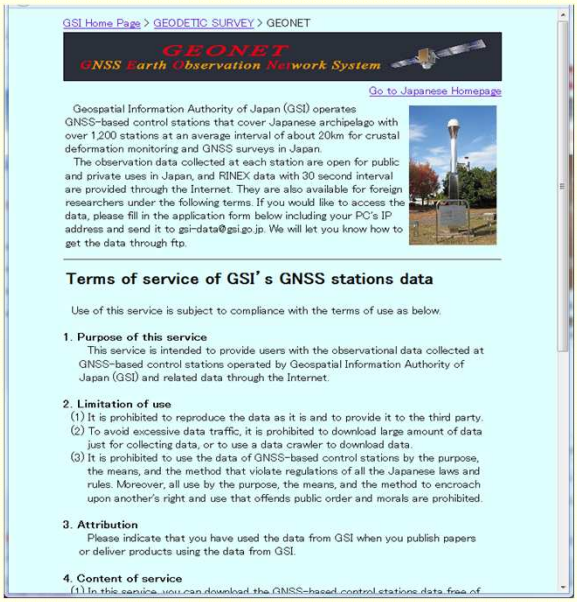
How to get GEONET data



GSI Home Page > GEODETIC SURVEY > GEONET

GEONET
GNSS Earth Observation Network System

Go to Japanese Homepage

Geospatial Information Authority of Japan (GSI) operates GNSS-based control stations that cover Japanese archipelago with over 1,200 stations at an average interval of about 20km for crustal deformation monitoring and GNSS surveys in Japan.
The observation data collected at each station are open for public and private uses in Japan, and RINEX data with 30 second interval are provided through the Internet. They are also available for foreign researchers under the following terms. If you would like to access the data, please fill in the application form below including your PC's IP address and send it to gsi-data@gsi.go.jp. We will let you know how to get the data through ftp.

Terms of service of GSI's GNSS stations data

Use of this service is subject to compliance with the terms of use as below.

1. Purpose of this service
This service is intended to provide users with the observational data collected at GNSS-based control stations operated by Geospatial Information Authority of Japan (GSI) and related data through the Internet.

2. Limitation of use
(1) It is prohibited to reproduce the data as it is and to provide it to the third party.
(2) To avoid excessive data traffic, it is prohibited to download large amount of data just for collecting data, or to use a data crawler to download data.
(3) It is prohibited to use the data of GNSS-based control stations by the purpose, the means, and the method that violate regulations of all the Japanese laws and rules. Moreover, all use by the purpose, the means, and the method to encroach upon another's right and use that offends public order and morals are prohibited.

3. Attribution
Please indicate that you have used the data from GSI when you publish papers or deliver products using the data from GSI.

4. Content of service
(1) In this service, you can download the GNSS-based control stations data free of

- 30sec epoch data
- Fill in the application form and send it to gsi-data@gsi.go.jp
- The application form is available from http://datahouse1.gsi.go.jp/terras/terras_english.html

http://datahouse1.gsi.go.jp/terras/terras_english.html

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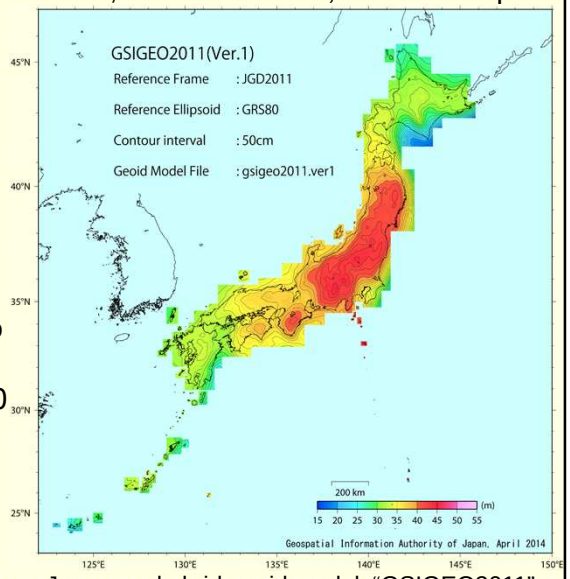
Japanese hybrid geoid model, "GSIGEO2011"

- Japanese new hybrid geoid model, "GSIGEO2011", has been open on April 1 2014.
  - Main purpose of the model is enabling height determination of third order benchmarks by GNSS surveying.
  - The model is established by fitting gravity geoid model, "JGEOID2008", to geoid heights determined from GPS/Leveling at 850 GEONET stations, 29 tidal stations and 142 benchmarks.



Japanese hybrid geoid model, "GSIGEO2011"

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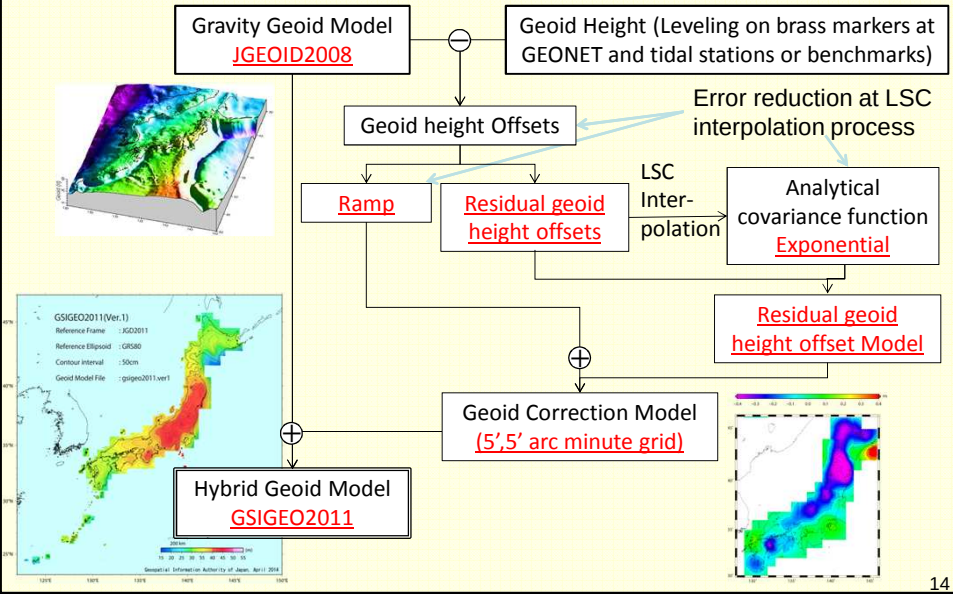
Japanese hybrid geoid model, "GSIGEO2011"

Schematic Flow Chart of Model Establishment



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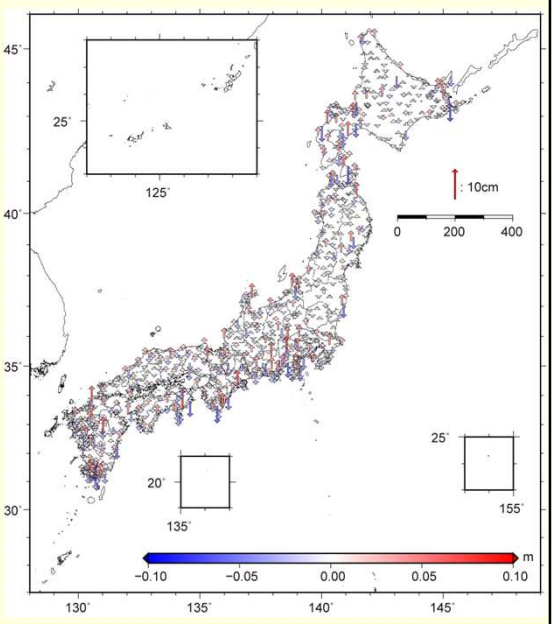
Evaluation of GSIGEO2011

- Comparing the model (GSIGEO2011) and inputs (GPS/Leveling) to evaluate the consistency of the model with Japanese vertical datum.

	GSIGEO2011 – GPS/Leveling
Average	0 cm
SD	1.9 cm
Max Difference	8.3 cm (-6.2 cm)



Differences between Model and GPS/Leveling Geoid Heights

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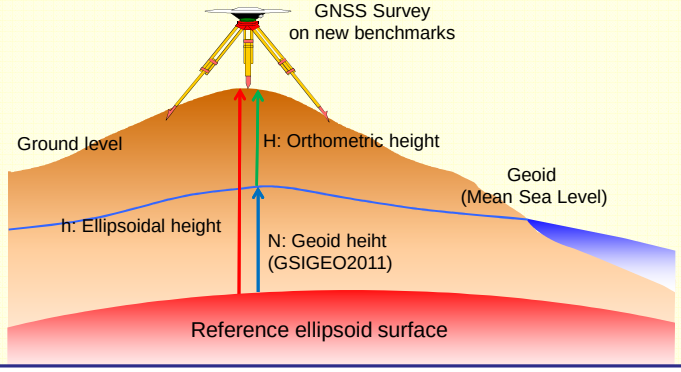
Height determination by GSIGEO2011 and GEONET

- Orthometric height determination by GNSS survey with GSIGEO2011 has been authorized and available as public survey in Japan mainland since April 1, 2014.
- The operation procedure for the survey was also defined and has been available since April 1, 2014.



Orthometric Height（H） = Ellipsoidal Height（h） - Geoid Height（N）

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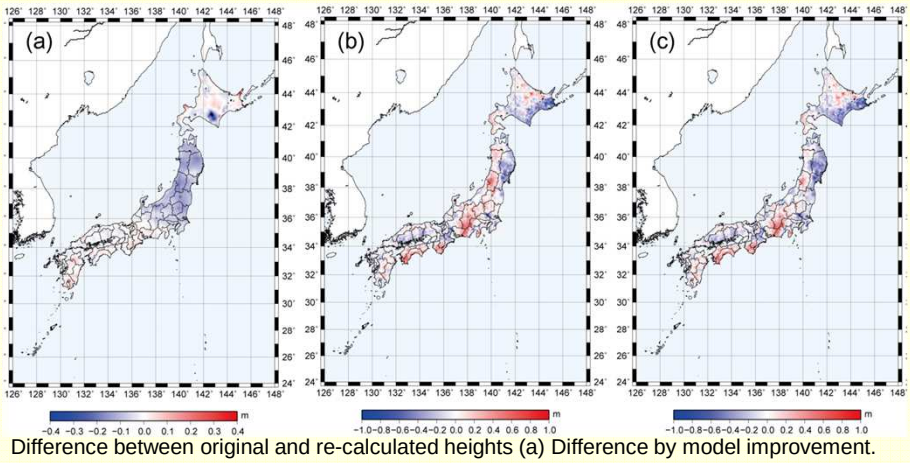
Re-calculation of heights of triangular points

- GSI re-calculated heights of triangular control points with GSIGEO2011, and revised the survey results on April 1, 2014.
- Difference between the original and the re-calculated heights is around 1m in maximum and 15cm in average. The difference contains both model improvement and vertical deformation by crustal movements from 1880's.



Difference between original and re-calculated heights (a) Difference by model improvement. (b) By cumulative crustal deformation since 1880's. (c) (a)+(b).

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Summary

- GSI has been operating GEONET, GNSS CORS network covering all over Japan for the past two decades.
- The purposes are to establish a regional reference frame consistent with the global frame and to monitor crustal deformation throughout the country.
- It supports a variety of applications and plays a major role as a national geodetic infrastructure.
- Japanese new hybrid geoid model, "GEIGEO2011" has been established on April 1 2014, and combination of the model and GEONET enables height determination for third order benchmarks in Japan by GNSS surveying.
- Orthometirc heights of triangular control points were also re-calculated with GSIGEO2011, and became available as revised survey results on April 1, 2014.

Two decades of experience in operation & analysis of GEONET provided GSI with accumulated knowledge & skills in CORS network, sufficient to extend technical assistance to other countries in an advanced and flexible manner.
GSI is ready for supporting construction/operation of CORS in your own country.
Contact: JICA training course Group
International Affairs Div., Planning Dept., GSI gsi-training@gsi.go.jp

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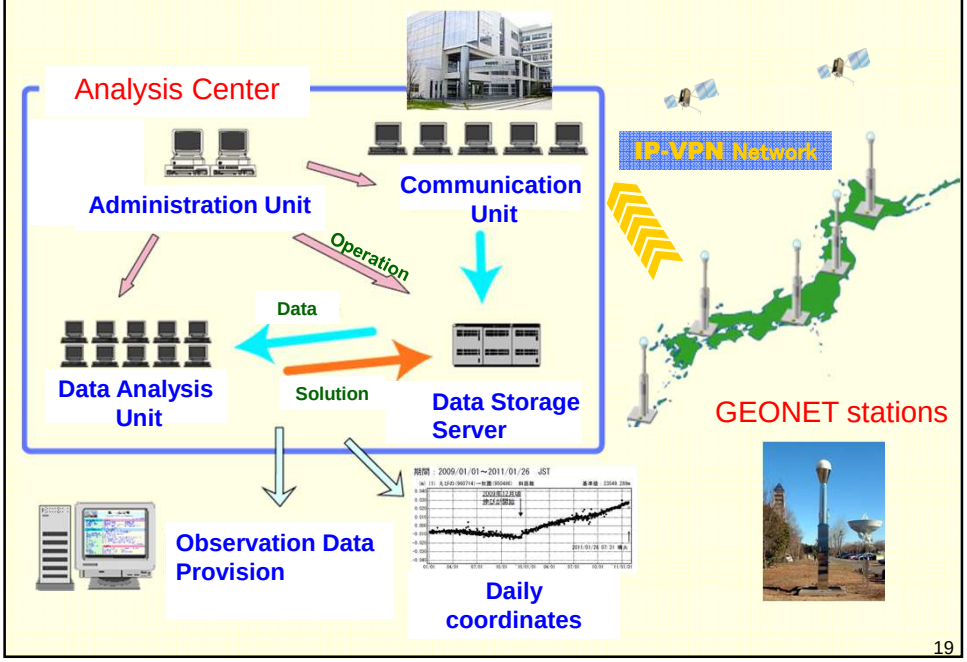
Data transmittion flow



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GEONET analysis strategy

- Hardware: HP ProLiant DL380 G5 Quad Core (x6)
  - CPU(Xeon X5355 2.66GHz) , L2 Cache (2x4GB), Memory (2GB) , HDD (146GB, 10krpm 2.5',(x2))
- Software: Bernese Ver.5.0
- Coordinate: ITRF2005
- Ellipsoid: GRS80
- PCV model: GSI original absolute
- Three types of routine analyses: F3,R3,Q3
  - Using 30 sec. data
- Higher frequency analyses: *(not for all sites)*
  - Real-time and post-processing by 1 sec. data

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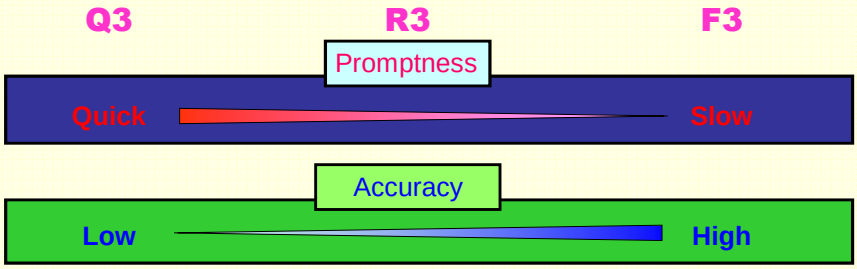
Routine analysis strategies (Post Processing)

Three types of routine analysis are provided

	Q3*(Quick)*	R3*(Rapid)*	F3*(Final)*
Data	6-hours	24-hours	24-hours
Orbit	IGS ultra-rapid	IGS rapid	IGS final
Schedule	Every 3 hours	Everyday	Every Sunday



And more … >>> Real–time analysis for tsunami mitigation

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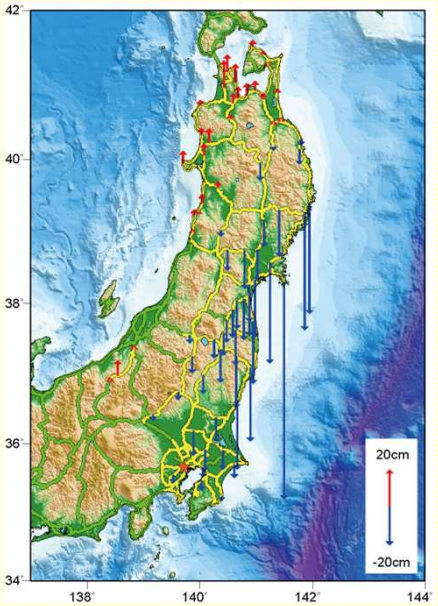
Re-surveying of benchmarks in Tohoku

- GSI re-surveyed orthmetric heights of almost all leveling routes and 55% of GEONET in Tohoku after 2011 Off the Pacific coast of Tohoku Earthquake.
- Displacements are up to 1.1m, and survey results were revised with the leveling survey.
- The revised orthometric heights are combined to GEIGEO2011, and the model is consistent with orthometric heights after the earthquake.

Yellow line is leveling route with re-surveying and green is without re-surveying.



First order leveling routes and amounts of revision

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