Policy on National Geodetic Control Points of Japan
- From Triangulation Control Points to GEONET -

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Contents

1. Geodetic control points in Japan
2. Policy on geodetic control points
3. GEONET performance for maintenance of geodetic reference frame
4. GEONET application for height determination
Introduction

○ Geospatial Information Authority of Japan (GSI) has been maintaining Japanese geodetic reference frame from the beginning of Meiji era, 120 years ago.
○ The reference frame was originally realized from triangulation surveys of triangulation control points.
○ Total number of the points reached 100,000 until the end of 20th century.
○ Considering performance of GNSS and needs for more accurate and efficient surveying utilizing GNSS, GSI decided to switch main geodetic control points from triangulation control points to CORS.
○ The change in the policy was publicly announced in Japan at the end of June 2014.

Geodetic Control Points in Japan

○ Reference frame in Japan was realized from triangulation surveys of triangulation control points.
○ The surveys had been conducted in a hierarchical way from first-order to forth-order and continued over a hundred years.
○ Total number exceeds 100,000 and maintenance cost has also been growing.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Sub-category</th>
<th>Ave. Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangulation control points</td>
<td>109,766</td>
<td>First order triangulation stations</td>
<td>25 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Second order triangulation stations</td>
<td>8 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Third order triangulation stations</td>
<td>4 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fourth order triangulation stations</td>
<td>1.5 km</td>
</tr>
<tr>
<td>Bench marks</td>
<td>17,050</td>
<td>Fundamental bench marks</td>
<td>150 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>First order bench marks</td>
<td>2 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Second order bench marks</td>
<td>2 km</td>
</tr>
<tr>
<td>Total</td>
<td>126,816</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Geodetic Control Points in Japan

- GSI started GNSS continuous observation from the middle of 1990’s.
- The observation system, named GNSS Earth Observation Network System (GEONET), has been gradually enhanced and covers Japan with over 1,300 stations with 20 km average spacing.
- Japanese geodetic reference frame has been mainly realized and maintained by GEONET.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>Sub-category</th>
<th>Ave. Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEONET CORS</td>
<td>1,318</td>
<td></td>
<td>20 km</td>
</tr>
<tr>
<td>(GNSS-based control stations)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(As of April 1 2015)

Geodetic Control Points in Japan

- Number of geodetic control points maintained by GSI

<table>
<thead>
<tr>
<th>Category</th>
<th># of stations</th>
<th>Sub-category</th>
<th>Average Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEONET stations</td>
<td>1,318</td>
<td></td>
<td>20 km</td>
</tr>
<tr>
<td>(GNSS-based control stations)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triangulation control points</td>
<td>109,766</td>
<td>First order triangulation stations</td>
<td>975 25 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Second order triangulation stations</td>
<td>5,045 8 km</td>
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<tr>
<td></td>
<td></td>
<td>Third order triangulation stations</td>
<td>31,927 4 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fourth order triangulation stations</td>
<td>71,819 1.5 km</td>
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<tr>
<td>Bench marks</td>
<td>17,050</td>
<td>Fundamental bench marks</td>
<td>84 150km</td>
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<td></td>
<td></td>
<td>First order bench marks</td>
<td>13,825 2 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Second order bench marks</td>
<td>3,141 2 km</td>
</tr>
<tr>
<td>Total</td>
<td>128,134</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(As of April 1 2015)

GSI decided to stop the maintenance of the most triangulation control points within 10 years
Policy on maintenance of control points

- Horizontal positions can be determined more accurately and efficiently by GNSS than by triangulation surveys.
- GSI is operating GEONET which covers Japan with 20km average spacing.
- GEONET can realize and maintain geodetic reference frame with a much smaller number of stations than triangulation control points.
- GSI decided to switch main geodetic control points from triangulation control points to GEONET stations and publicly announced a change at the end of June 2014.
- In the announcement, GSI stated:
  * GSI does not actively maintain triangulation control points and stop the maintenance of most of them within 10 years.
  * GSI makes the best of GEONET for realizing and maintaining geodetic reference frame in Japan.

Crustal deformation detected by GEONET

- The 2011 Off the Pacific coast of Tohoku Earthquake (the Great East Japan Earthquake) (March 11, 2011) caused unexpectedly huge crustal deformation and tsunami.
- Almost all of GEONET stations survived the disaster and continuously provided accurate positions through and after the event.
- GEONET is one of key enablers for Japan to recover from the huge earthquake efficiently by providing the accurate positions for all restoration works.
Co-seismic Movement by Great East Japan Earthquake

**Horizontal**

- 130 cm (Oshika)
- Tokyo (origin) ~20 cm

**Vertical**

- 120 cm (Oshika)
- Tokyo (origin) ~5 cm

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**Revision of survey results by GEONET**

**East Japan**
- Survey results were closed (Mar. 14)
- GNSS & VLBI observations & analyses.
- Revised new survey results were re-opened (May. 31)

**West Japan & Hokkaido**
- Not revised

**Difference between the old and the new datum**

All new data set is called “Geodetic Coordinates 2011”
Semi Dynamic Correction by GEONET

- Japan is located on boundaries of active plates.
- Crustal deformation is continuously occurred through the islands.
- Cumulative deformation decreases accuracy of survey results. As time goes, differences between survey results and "real" positions are getting larger and larger.

Semi-Dynamic Correction is a method to remove crustal deformation from survey results and improve consistency. Crustal deformation of Japan is modeled from a velocity field detected by GEONET observation. Parameters for the correction are calculated from the model and applied for land surveys.

Hybrid geoid model of Japan, “GSIGEO2011”

- GSIGEO2011 is developed to enable orthometric height determination by GNSS surveying.
- The model is established by fitting gravity geoid model of Japan, “JGEOID2008”, to geoid heights determined from GNSS/Leveling at 850 GEONET stations, 29 tidal stations and 142 benchmarks.
- GSIGEO2011 has been open on April 1 2014 and available for public survey in Japan.
Japanese hybrid geoid model, “GSIGEO2011”

Schematic flow of development of GSIGEO2011

Gravity Geoid Model
JGEOID2008

Geoid Heights
(GNSS/leveling at
GEONET stations or
benchmarks)

Geoid height Offsets

Error reduction at LSC

LSC Inter-
polation

Analytical
covariance function
Exponential

Residual geoid-
height offsets

Residual geoid
height offset Model

Ramp

Hybrid Geoid Model
GSIGEO2011

Geoid Correction Model
(5',5' arc minute grid)

Evaluation of GSIGEO2011

Reproduction errors (differences between GSIGEO2011 and GNSS/leveling).

<table>
<thead>
<tr>
<th></th>
<th>Reproduction error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0 mm</td>
</tr>
<tr>
<td>5D</td>
<td>1.9 mm</td>
</tr>
<tr>
<td>Max Difference</td>
<td>8.3 mm [-6.2 mm]</td>
</tr>
</tbody>
</table>

Summary

1. GSI decided to switch main geodetic control points from triangulation control points to GEONET stations.
2. GEONET is essential infrastructure for realizing and maintaining geodetic reference frame in Japan, especially detecting and measuring crustal deformation.
3. GEONET is also utilized for orthometric height determination by GNSS surveying.

Thank you for your attention.