The New Application of GEONET for Multi-GNSS Observation and Height Determination with New Japanese Geoid Model

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SUMMARY

GSI has established and operated nationwide GNSS continuous observation network, GEONET, since 1996. GEONET has been gradually upgraded in its system and receiving signals, and GEONET GNSS observation data, including GPS, QZSS and GLONASS, has been opened to users since July 2012. GEONET has already become essential infrastructure for not only land survey, but also geospatial information management and crustal deformation monitoring. The system has also showed great performance in several fields such as prompt revision of survey results at the 2011 off the Pacific coast of Tohoku Earthquake and still in challenge to monitor crustal movement and earthquake magnitude in real-time.

GSI also utilized GEONET stations for establishment of Japanese hybrid geoid model, GSIGEO2011. By combining GEONET GNSS observation data and the geoid model, orthometric height determination through GNSS survey has been available for surveys for public projects in Japan. Orthometric heights of triangular control points in Japan are also re-calculated with the geoid model and the re-calculated heights shows great improvement in consistency with heights of GEONET stations.

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1. INTRODUCTION

GSI has established and operated nationwide GNSS continuous observation network, GEONET, since 1996 (Hatanaka et al., 2003). GEONET GNSS observation data, including GPS, QZSS and GLONASS, has been opened to users, and GEONET has become essential infrastructure for not only land survey, but also geospatial information management and crustal deformation monitoring. The system has showed great performance in several fields such as prompt revision of survey results at the 2011 off the Pacific coast of Tohoku Earthquake.

GEONET stations are also utilized for establishment of Japanese hybrid geoid model, GSIGEO2011. By combining GEONET GNSS observation data and the geoid model, orthometric height determination through GNSS survey became available for surveys for public projects in Japan.

2. GEONET

2.1 Overview of GEONET

Currently, GSI has Global Navigation Satellite System (GNSS) observation stations at approximately 1,300 locations nationwide to conduct continuous GNSS observations to realize the geodetic reference frame of Japan as well as to monitor crustal deformation. The entire system comprised of these observation stations and the central station in Tsukuba for collecting, analyzing and distributing these data is called GEONET.

Significant crustal deformation caused by the 2011 off the Pacific coast of Tohoku Earthquake was detected by GEONET. Figure 1 shows the horizontal movement, and Figure 2 the vertical movement, of GEONET sites in northeastern Japan (GSI, 2011). The maximum movement is recorded at the Oshika site in Ishinomaki City, Miyagi Prefecture, and comprises about 5.3 m horizontal movement toward the east to south-east and vertical subsidence of up to 1.2 m.

2.2 Data Provision

GNSS data from GEONET stations are available for these public surveys from the GSI website (http://terras.gsi.go.jp/ja/index.html). These data contain observation data per 30 seconds and broadcast ephemerides in RINEX format. On July 13, 2012, at a part of GEONET stations, GSI started providing the observation data received from the Quasi-Zenith Satellites System (QZSS) and GLONASS in addition to the existing GPS. On May 10, 2013, this was extended to almost all GEONET stations.

QZSS is a regional space-based positioning system. The system covers regions in East Asia and Oceania centering on Japan and is designed to enable users in the coverage area to receive QZS signals from a high elevation angle at all times. The first satellite of QZSS was launched in September 2010, and four satellites constellation is planned to start operation in 2018 by adding three more satellites. Recently, RINEX ver. 3.02 that officially supports QZSS was released, and GSI will provide the data with it from 2014.

GSI collects real-time data with 1 second intervals from 1,220 stations. These data are provided to two private enterprises via a distributor, and utilized for generating correction data for network-based RTK.

2.3 Analysis of GEONET data

GEONET has three different routine analysis strategies; Quick, Rapid and Final. Quick analysis is executed every three hours with 6 hour data and utilized especially for monitoring crustal movement. Rapid analysis is done every day with 24 hour data. Final analysis is executed with IGS final orbits. These analyses are performed with BERNESE ver.5.0.

GSI has been developing a new GEONET real-time analysis system, named REGARD (Real-time GEONET Analysis System for Rapid Deformation Monitoring). It is designed for estimating permanent displacement field and Mw of giant earthquakes and notify the results in real-time. GSI verified that the system successfully could estimate appropriate Mw values just after a couple of minutes in case of large events (e.g. Mw8.9 in the 2011 Tohoku earthquake). It is planned to focus on exploiting to tsunami warning.

3. Japanese hybrid geoid model and its application for land survey

3.1 Japanese Hybrid geoid Model, "GSIGEO2011"

GSI established Japanese hybrid geoid model, "GSIGEO2011", which covers the whole area of Japan archipelago (Fig. 4). The model is created by combining Japanese gravity geoid model, JGEOID2008 (Kuroishi, 2009), and geoid heights of 850 GEONET stations. Orthometric heights of the GEONET stations have been determined by leveling survey from the first order leveling bench marks, and the geoid heights of the stations are calculated from the orthometric heights and ellipsoidal heights. Least square collocation method is adopted to fit the gravity geoid model to the calculated geoid heights, and the fitting between the calculated geoid heights and geoid heights of GSIGEO2011 at the stations is approximately under 2cm in RMS (Fig. 5).

In the area affected by crustal deformation of the 2011 off the Pacific coast of Tohoku Earthquake, GSI re-surveyed orthmetric heights of almost all leveling routes and 55% of GEONET stations (Fig. 6) and revised survey results of the benchmarks. The revised orthometric heights of the stations are combined to GEIGEO2011, and the model is consistent with orthometric heights after the earthquake.

3.2 Height Determination by GNSS Survey Utilizing "GSIGEO2011"

Orthometric height determination by GNSS survey with the new hybrid geoid model has been authorized by the government as public surveys in Japan and available for public surveys in Japan mainland since April 1, 2014. GSI also defined the operation procedure for the survey, which includes height determination method through GNSS observation with the model, GSIGEO2011, and the procedure has been available since April 1, 2014.

3.3 Re-calculation of Orthometric Heights of Triangular Control Points

GSI also re-calculated heights of triangular control points with the new model, GSIGEO2011, and revised the survey results on April 1, 2014. The difference between the original and the re-calculated heights is around 1m in maximum and 15cm in average (Fig. 7). The surveys of triangular control points started in 1880's, and the difference derives from both model improvement and vertical deformation caused by cumulative crustal movements in Japan from 1880's. The revised results are available in GSI website, and it makes all users to access more accurate and consistent heights information in Japan.

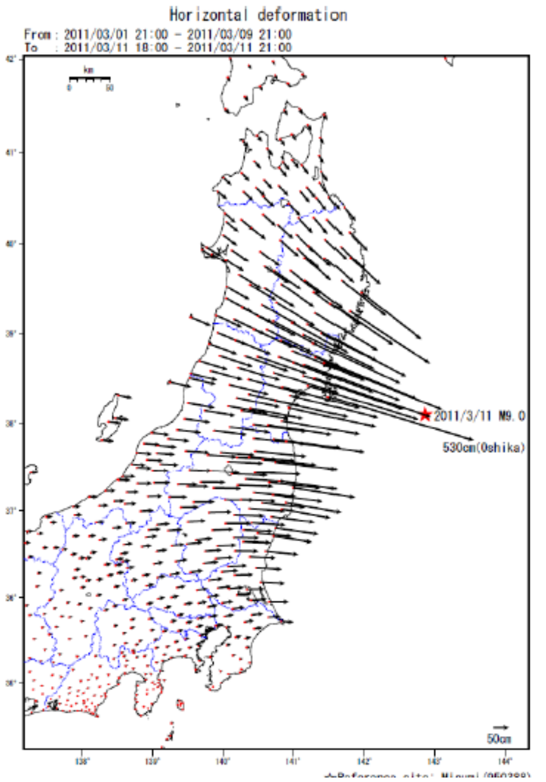

Fig. 1 Crustal deformation (horizontal) associated with the 2011 off the Pacific coast of Tohoku Earthquake that occurred on March 11, 2011.

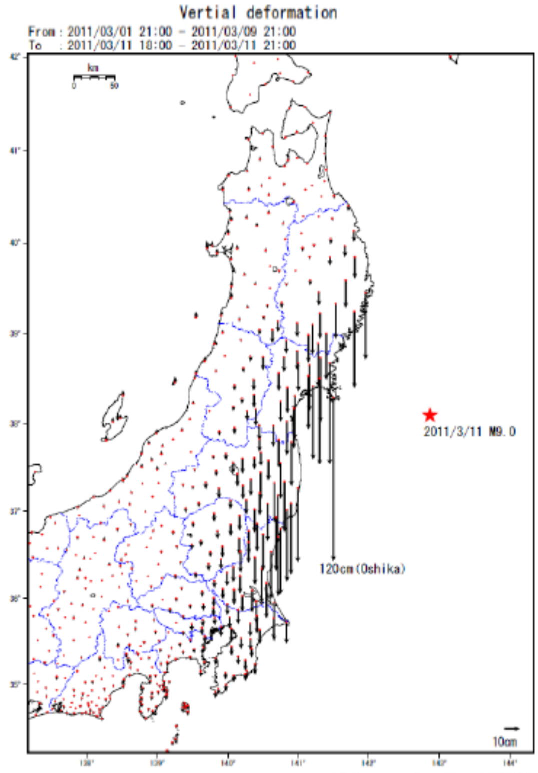

Fig. 2 Crustal deformation (vertical) associated with the 2011 off the Pacific coast of Tohoku Earthquake that occurred on March 11, 2011.

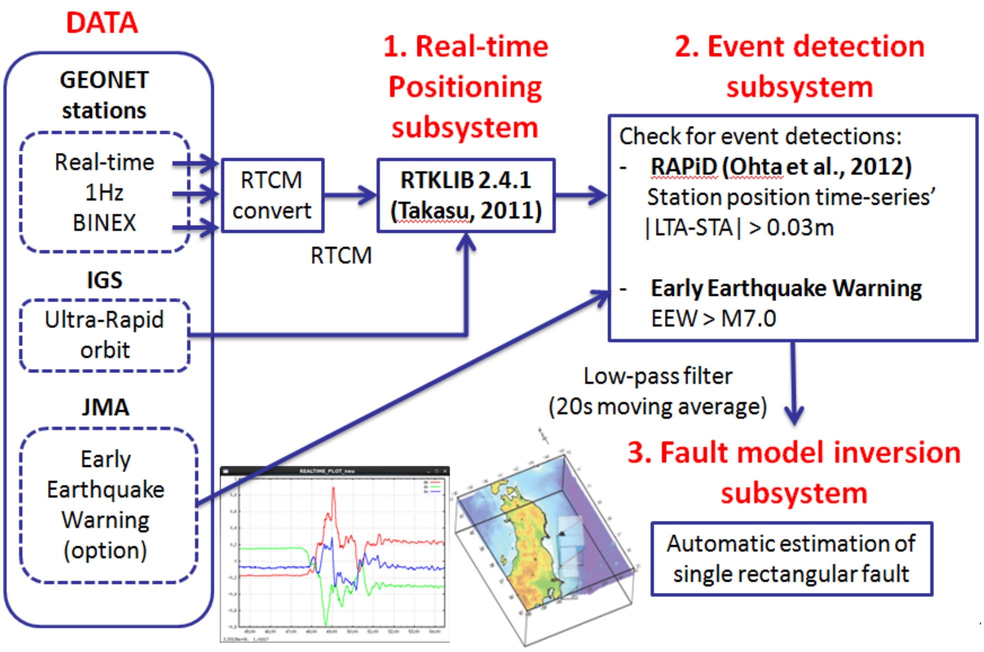

Fig.3 Flow diagram of REGARD.

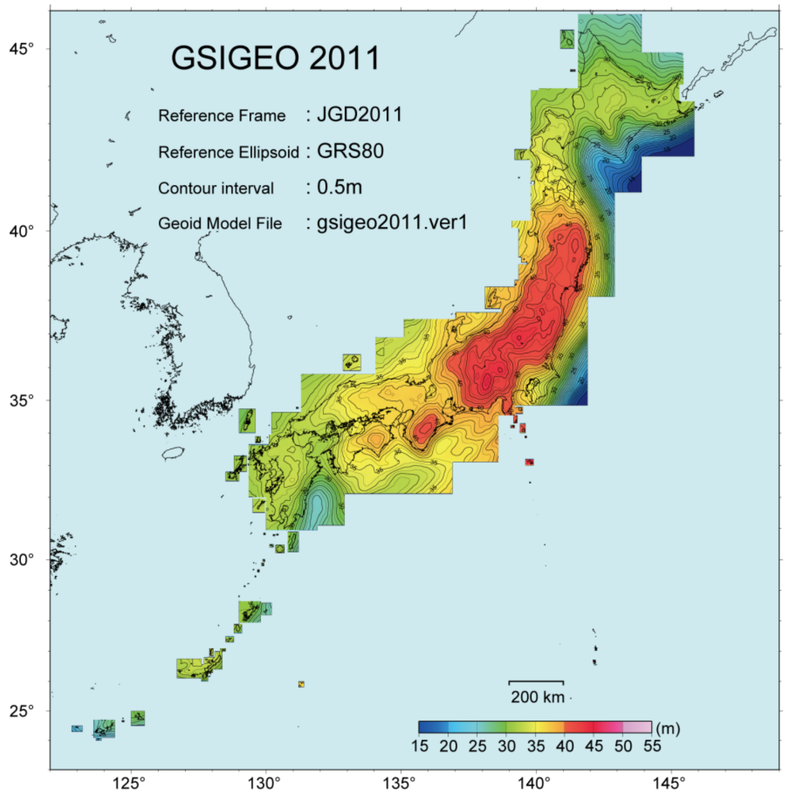

Fig.4 Japanese new hybrid geoid model, "GSIGEO2011".

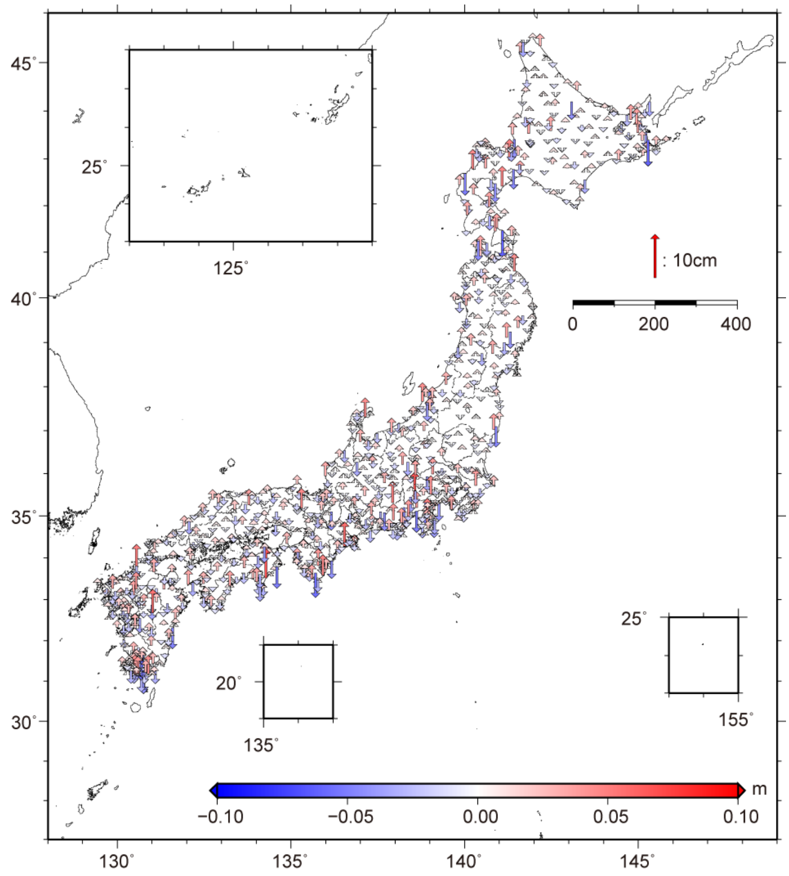

Fig.5 Difference between input (GNSS-Leveling) and GSIGEO2011.

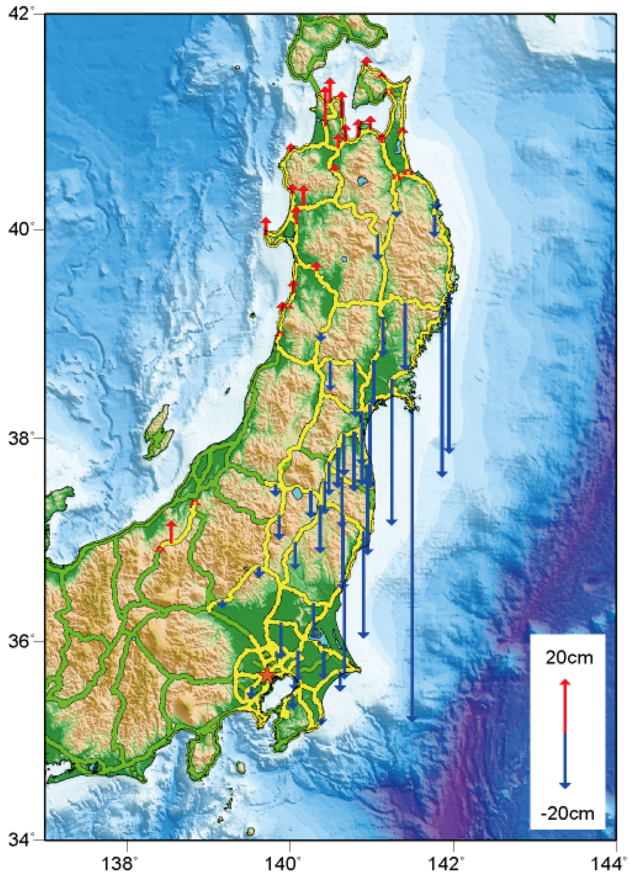

Fig.6 First order leveling route in Tohoku area, Japan . Yellow line is re-surveyed leveling route after Tohoku Earthquake. Red and blue allows show differences between original and re-calculated heights of benchmarks.

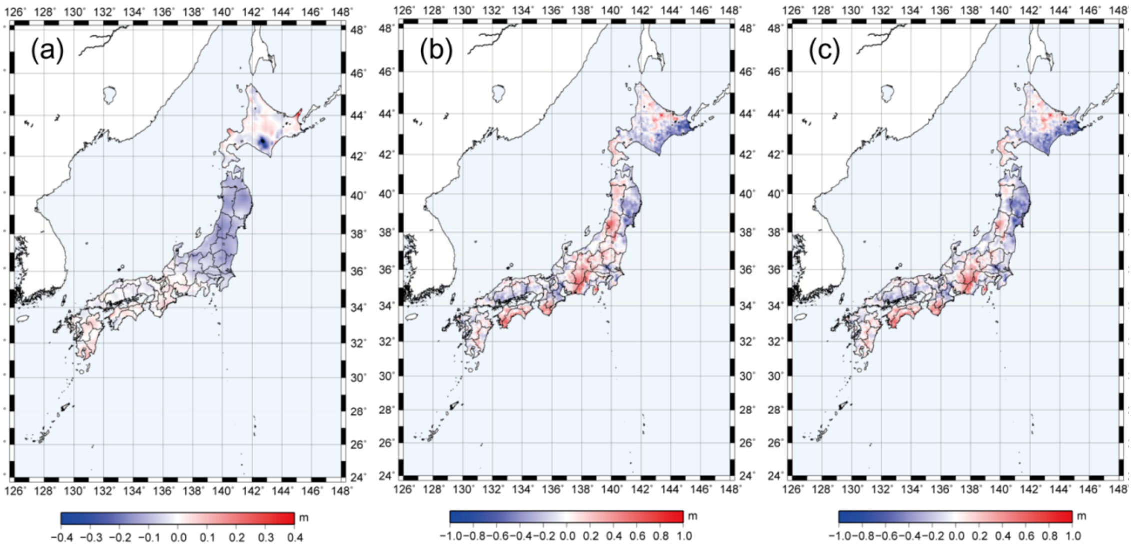

Fig.7 Difference between original and re-calculated heights of triangular control points. (a) Difference by model improvement. (b) By cumulative crustal deformation since 1880's. (c) (a)+(b).

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BIOGRAPHICAL NOTES

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