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Analysis of Crustal Movement Velocity After the Great Earthquake using GNSS

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Abstract
The great Tohoku earthquake which occurred on March 11, 2011, caused crustal movements in Japan. In this study, crustal movement speed of study area was calculated using GNSS observation data. The data of MIZU and KSMV which are CORS of International GNSS Service was analysed from 2011 to 2015. Data was analysed with Bernese 5.0 S/W using precise point positioning method. As a result, crustal movement speed of X, Y, Z axis were calculated. The speeds of MIZU and KSMV were -0.0274m/year, -0.0016m/year, -0.0017m/year and -0.008m/year, -0.004m/year, -0.0035m/year each in WGS84 coordinate system. Crustal movement speed were different from the existing result calculated by previous observation data before 2015. It is expected that the crustal movement speed of Japan can be used for related studies on geophysical investigation.

Keywords: Earthquake, Crustal Movement, GNSS, Precise Point Positioning, International GNSS Service, Continuous Observation Reference Station

1. Introduction

A strong earthquake of magnitude 9.0 on the Richter scale struck on the sea of Tohoku in North-eastern Japan on March 11, 2011[1-2]. Due to this earthquake, a big earthquake and tsunami struck the coastal area from Sanriku to Ibaraki neighboring Tohoku area. This earthquake caused 26,000 deaths and incalculable socio-economic damage such as building collapses and bankruptcies of up to 1,000 enterprises [3-4]. NASA (National Aeronautics and Space Administration), JPL (Jet Propulsion Laboratory), and many other agencies announced crustal deformation in Japan right after the Tohoku earthquake [5-6]. However, 5 years after it, there are not enough research on crustal movement of Japan region yet. In this study, the speed of crustal movement after the Tohoku earthquake was calculated using post-earthquake GNSS observation data processed with PPP (Precise Point Positioning) method. In addition, the study provides velocity variation of crustal movement after the earthquake through comparison with the velocity of crustal movement announced by ITRF (International Terrestrial Reference Frame). Fig. 1 shows diagram of the study flow.

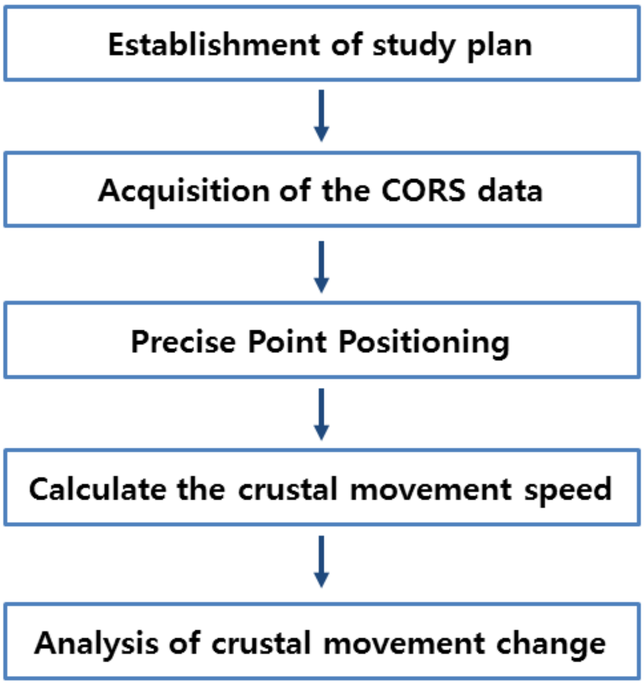

Fig. 1. Study Flow

2. Precise Point Positioning

In this study, the observation data of Japan's GNSS CORS were processed by PPP by month, using Bernese Software. Among the IGS CORS in Japan, MIZU and KSMV which are the nearest from the epicenter were designated as a study area. The observation data from April, 2011 which is after the earthquake to March, 2015 are used. Fig. 2 shows Study area.

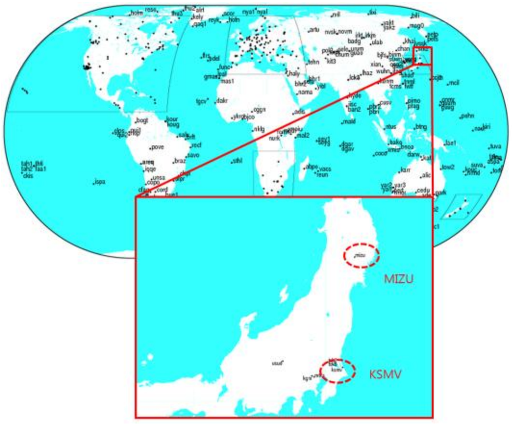

Fig. 2. Study area

The deviations occurred during the processing of GNSS data due to physical movement of the earth and pole movement and atmospheric load, must be removed using a suitable model [1-3]. Bernese removed these correction factors by using satellite orbit and all kinds of models provided by NASA JPL, AIUB (Astronomical Institut Universität Bern)[4-5]. For the precise positioning using observation data, data processing was performed by using at least a 15° elevation angle and precise ephemeris for removing multipath and positioning of the GNSS satellites. Table 1 and table 2 show results of data processing.

Table 1. Results of the MIZU

Date	X(m)	Y(m)	Z(m)
2011-04-01	-3857169.720	3108693.652	4004040.640
2011-05-01	-3857169.807	3108693.580	4004040.608
2011-06-01	-3857169.862	3108693.530	4004040.582
2011-07-01	-3857169.912	3108693.506	4004040.580
2011-08-01	-3857169.951	3108693.483	4004040.562
2011-09-01	-3857169.999	3108693.471	4004040.554
⋮	⋮	⋮	⋮
2014-12-01	-3857170.971	3108692.885	4004040.249
2015-01-01	-3857170.995	3108692.864	4004040.238
2015-02-01	-3857171.022	3108692.856	4004040.231
2015-03-01	-3857171.039	3108692.840	4004040.222

Table 2. Results of the KSMV

Date	X(m)	Y(m)	Z(m)
2011-04-01	-3997525.804	3276870.211	3724218.231
2011-05-01	-3997525.878	3276870.185	3724218.230
2011-06-01	-3997525.893	3276870.163	3724218.212
2011-07-01	-3997525.909	3276870.155	3724218.199
2011-08-01	-3997525.945	3276870.157	3724218.212
2011-09-01	-3997525.956	3276870.161	3724218.208
⋮	⋮	⋮	⋮
2014-12-01	-3997526.215	3276870.055	3724218.118
2015-01-01	-3997526.256	3276870.065	3724218.132
2015-02-01	-3997526.221	3276870.048	3724218.100
2015-03-01	-3997526.216	3276870.046	3724218.095

3. Analysis of Crustal Movement Speed

In this study, the GNSS observation data were processed using the PPP for the monitoring of the crustal movement speed about MIZU and KSMV. And crustal movement speed was calculated. The PPP results of MIZU and KSMV were moving in the direction of the X, Y and Z axis are decreasing. Figures 3 and 4 show the crustal movement of MIZU and KSMV.

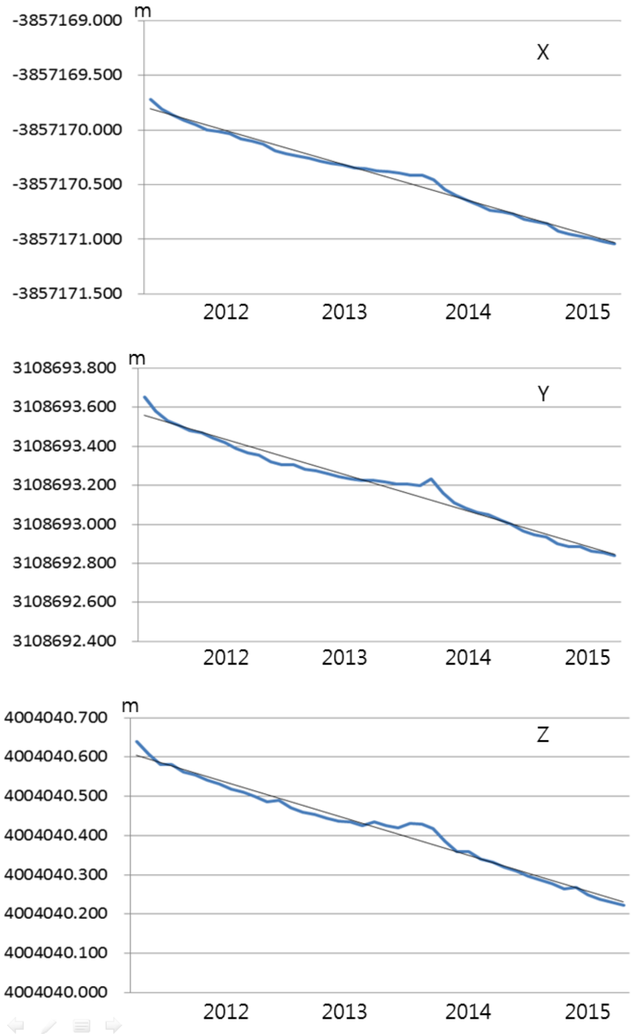

Fig. 3. Crustal Movement of MIZU

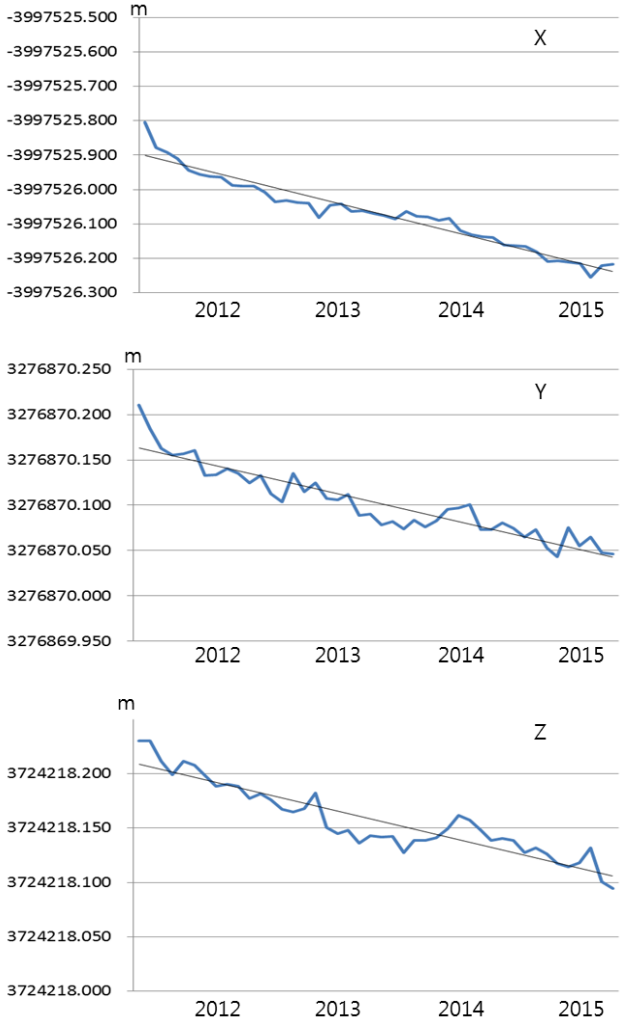

Fig. 4. Crustal Movement of KSMV

To calculate the crustal movement speed of MIZU and KSMV, The normal-equation solution of each session was processed. The crustal movement speed of MIZU was -0.0274m/year, -0.0016m/year, -0.0017m/year and of KSMV was -0.008m/year, -0.004m/year, -0.0035m/year in each components of the ITRF coordinate system. The results of this study was compared with the speed of crustal movement from ITRF2008. Table 3 shows the comparison between the study result and the crustal movement speed of ITRF2008. As seen in table 3, there is a slight difference of crustal movement speed between the results of study and ITRF2008. This is because that ITRF2008 didn't use the recent data after the earthquake for calculating crustal movement speed.

Table 3. Comparison of Crustal Movement Speed

CORS		Crustal Movement Speed		
		X(m/year)	Y(m/year)	Z(m/year)
MIZU	This Study	-0.0274	-0.0016	-0.0017
	ITRF2008	0.0017	0.0071	-0.0078
KSMV	This Study	-0.008	-0.004	-0.0035
	ITRF2008	-0.001	0.0072	-0.0069

4. Conclusion

In this study, crustal movement speed of the study area was calculated using PPP method. And the comparison with the crustal movement speed of ITRF2008 was performed. The conclusions of this study were followings. GNSS observation data of MIZU and KSMV from April, 2011 to March, 2015 processed with PPP were used to calculate crustal movement speed of each. The crustal movement speed of MIZU was -0.0274m/year, -0.0016m/year, -0.0017m/year and results of KSMV was -0.008m/year, -0.004m/year, -0.0035m/year in each components of the ITRF coordinate system. The crustal movement speed calculated from the study was compared with the crustal movement speed from ITRF2008. The result and the one from ITRF2008 showed different values. This is because that ITRF2008 didn't use the recent data after the earthquake for calculating crustal movement speed. It is necessary to calculate the speed of crustal movement in Japan for predicting earthquakes and monitoring diastrophism.

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