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Procedia Environmental Sciences 20 (2014) 678 – 683

Procedia
Environmental Sciences

The 4th International Conference on Sustainable Future for Human Security, SustaiN 2013

Multi-epoch GNSS Data Analysis on Geodynamics Study of Central Java

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Abstract

Geometrics method based on multi-epoch GNNS data is one of the methods used in the geodynamic study. Three epochs of GNNS measurement at some benchmarks are used to measure general feature of the geodynamic of Java Island in 3 Dimensions. The coordinate solutions have been determined using simultaneous network adjustment connected to the global network available around Indonesia; those are: COCO, BAN2, PIMO, DGAR, NTUS and DARW. The processing of three days GNNS (Rinex) data have been done through a daily processing using GAMIT and a combination processing using GLOBK. The output of the computation shows that the precision of the baseline ranges from 1 – 5 mm, while the precision of the daily and the combination estimated coordinate ranges from 1 to 6 mm. Based on the coordinate difference, the surface velocity of the site is ranged from 0.6 to 7.3 mm/year, with the direction of the movement to the eastward. In general, the precision of the Y coordinate components, which represents the height components in the Indonesia area, is always lower than the X and Z components.

Selection and peer-review under responsibility of the SustaiN conference committee and supported by Kyoto University; (RISH), (OPIR), (GCOE-ARS) and (GSS) as co-hosts

Keywords: *Geodynamics, GNSS data, Geometrics Geodesi, statistical analysis.*

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doi:10.1016/j.proenv.2014.03.081

1. Background

Java Island is one of the main islands in Indonesia with populations of about 136.6 million or about 58% of total Indonesian populations. It is located in one of the most geodynamic area in the world, in which the Australian plate subducts the Eurasian plate so that the islands move to the north with average velocity of about 2 cm/year. People should always be prepared for the possibility of earthquakes, landslides, volcanoes and Tsunami hazards which often occur over the area. Therefore, the geodynamic studies of the area are necessary, especially for hazard mitigation purposes. Among several methods available, there is the geometric method using the repeated or continuous Global Navigation Satellite System (GNSS) measurement.

In the beginning, GNSS which was started by Global Positioning System (GPS) satellite was widely used by the military. Recently, it is being largely used by civilians, scientific and industrial communities and increasing important role in high precision surveying and geodetic application. Further refinements for greater precision of GNSS long distance positioning are the continuous objectives of GNSS research and development. This research focused on customizing methods for processing and analyzing multi epoch GNSS data to detect the geodynamic of Java Island.

The widespread usage of GNSS in displacement measurement with millimeters-level of precision requires some special precautions to increase the precision in the output. Obtaining such a level of precision entails eliminating or reducing some sources of error, i.e. by designing special equipment for precise antenna height reading, using forced centering equipment and applying a special measuring technique for long-baselines [1]. In some cases, even these special precautions may be insufficient to achieve the necessary precision level. Supporting GNSS measurements with appropriate measurement techniques and processing methods would be an advantageous improvement.

2. Data and Methods

Eight sample benchmarks, namely BAKO (Cibinong), CCIR (Cirebon), CPKL (Pekalongan) and CSEM (Semarang), CPWD (Purwodadi), CPBL (Purbalingga), CMGL (Magelang) and JOGS (Yogyakarta) were observed for their displacements using the GNSS technique in three epochs of 26-29 June 2010 (doys 177-181), 13-16 July 2011 (doys 183-186) and 8-11 July 2012 (doys 190-193) using Trimble geodetic series GNSS receiver. The receivers were designed for double-difference carrier phase observation with dual frequency L1 and L2.

The observation was carried out using GNSS relative technique with the field occupation criteria as follows:

- Each session was planned for a continuous period of 24-hour on a daily basis with a bigger internal memory.
- The observation recording interval was 15 seconds in each session with at least 15° cut-off angle of configuration.
- During all surveys, Trimble's Compact L1/L2 with ground plane antenna was used to reduce the multipath effects and to achieve the highest possible precision.

The processing treated the benchmark as an observed object station and utilized several global International GNSS Service (IGS) reference stations, such as COCO (Cocos Island), BAN2 (Bangalore), PIMO (Philippines), DGAR (Diego Garcia Island), NTUS (Philippines), and DARW (Darwin). The IGS RINEX GNSS data, precise ephemeris data (sp3-file), broadcast ephemeris data (brcd-file) were downloaded for each day from IGS web: http://igscb.jpl.nasa.gov/. The network configuration of the global station and the benchmark is illustrated in Figure 1.

Data from GNSS receivers were stored in an original binary format and required conversion from binary to RINEX format. The output files in RINEX format were also checked, to ensure correct conversion and data header corresponds to the correct site.

The observation data used in the project required validation before further processing to fulfill the required standard of the project, or needed to be repeated. This preliminary step should be verified before continuing with the next data processing step. In this project, GNSS data were validated using TEQC program, named after its three main functions: Translating, Editing and Quality Checking, which can be accomplished separately or in combination [3].

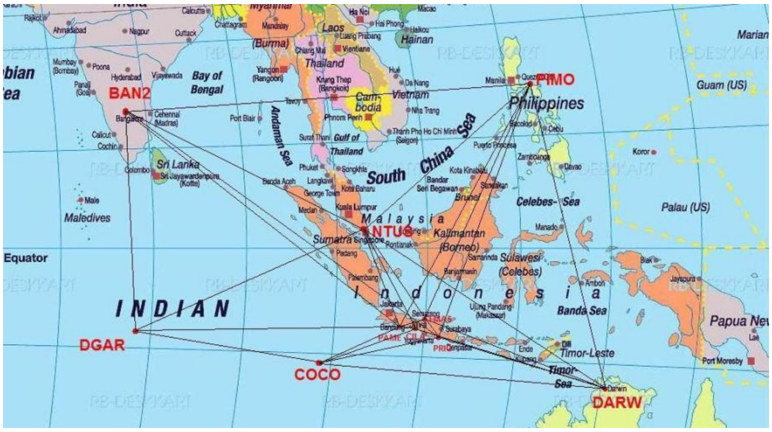

Fig. 1. Configuration network of IGS stations and bencmarks (Source: [2])

In order to obtain a high quality result, processing of the GNSS data implemented GAMIT/GLOBK software to determine the coordinate and its standard deviation. The software has been developed for precise positioning purpose and offers many options to reduce errors in baseline processing [4]. GAMIT was used to produce estimates and associated covariance matrix of daily position of each site with loose constraints on the parameters. Further, all covariance were used as input for a combined solution (site position and velocity) using the GLOBK based on Kalman filter method.

Two types of analysis were used to determine the difference between the 2010, 2011 and 2012 solutions: raw and global analysis using the GLOBK combined solution. Raw analysis was performed by differencing the estimated coordinates of GNSS points from the 2010, 2011 and 2012 solution. In the global analysis, the h-files from each campaign were processed in a single GLOBK run as a GLOBK combined solution. In this way, the changes in the position of each GNSS point between the three epochs were determined. The displacement analysis was based on this result.

3. Evaluation of the GNNS Data

The output of GLOBK software is information of the baseline and its precision. Table 1 depicts the baseline between the sites, with the baseline ranged from 38 km to 226 km, which is characterized as short-baseline i.e. less than 1,000km. The precision of the baseline ranged from 1 to 5 mm, which was classified as a high precision measurement. Meanwhile, the baseline between the site and the IGS stations that were used as reference points (not shown in this paper) ranged more than 1,000 km which is characterized as a long-baseline with the precision also ranged from 1 to 5 mm. Both baseline shad the same high precision measurement which fulfilled the requirement for geodynamic analysis purposes.

Further, the baselines which were least square were adjusted using the GAMIT package program, resulting in the daily site position and their precision. Figure 2 shows the daily 3D coordinate of the site, expressed in UTM system with their precision in normalized rms (nrms) and weighted rms (wrms) values. The values showed the postfit of the phase residual for the single site and satellite and used these to edit and evaluate the data. The computation generated results with wrms scatters of 1.1 to 2.8 mm in the north and east directions. Meanwhile, larger wrms showed 5.3 mm for 2010 and 7.5 mm for 2012 in up direction.

Table 1. The length of baseline and its precision

No.	Stations From	Stations to	Length (m)	Sigma	No	Stations From	Stations To	Length (m)	Sigma
1	JOGS_GPS	CCIR_GPS	226873,119	0,00197	12	JOGS_GPS	CPBL_GPS	113078,482	0,00202
2	CMGL_GPS	CCIR_GPS	201316,688	0,00212	13	CPKL_GPS	CPBL_GPS	64903,835	0,00166
3	CPKL_GPS	CCIR_GPS	123986,120	0,00208	14	CPWD_GPS	CPKL_GPS	139470,860	0,00434
4	CPBL_GPS	CCIR_GPS	115784,736	0,00198	15	CSEM_GPS	CPKL_GPS	78967,504	0,00182
5	CPWD_GPS	CMGL_GPS	87700,230	0,00403	16	JOGS_GPS	CPKL_GPS	123844,656	0,00166
6	CSEM_GPS	CMGL_GPS	56842,164	0,00147	17	CPWD_GPS	CSEM_GPS	60567,935	0,00428
7	JOGS_GPS	CMGL_GPS	38666,776	0,00161	18	CPWD_GPS	JOGS_GPS	105001,277	0,00356
8	CMGL_GPS	CPKL_GPS	88869,688	0,00183	19	CPWD_GPS	CCIR_GPS	263434,702	0,00438
9	CMGL_GPS	CPBL_GPS	94634,057	0,00217	20	CSEM_GPS	JOGS_GPS	92171,299	0,00142
10	CPWD_GPS	CPBL_GPS	174198,952	0,00430	21	CSEM_GPS	CCIR_GPS	202944,952	0,00195
11	CSEM_GPS	CPBL_GPS	120332,678	0,00187					

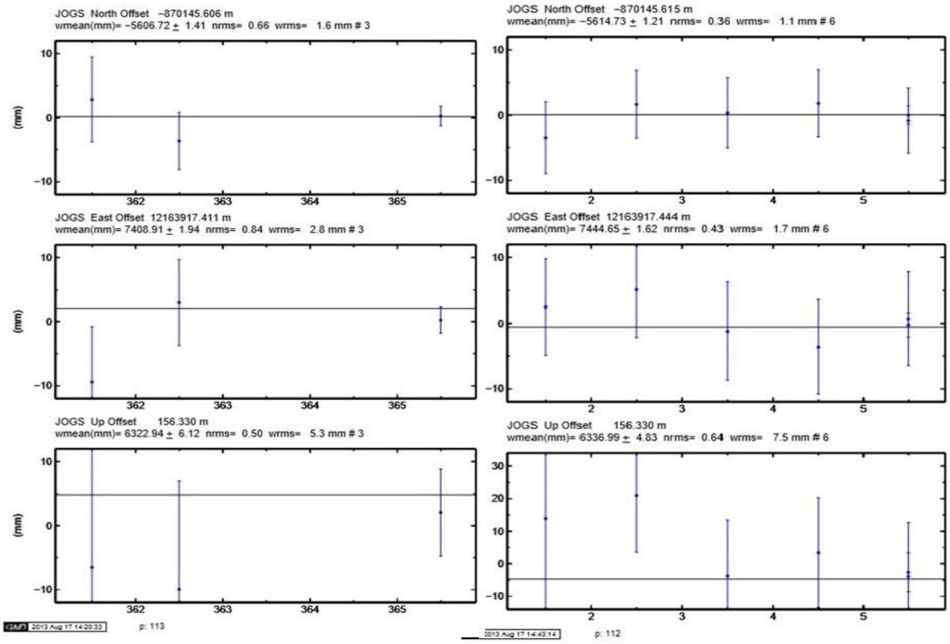

Fig. 2. Daily estimates of coordinate and postfit phase residual of Jogyakarta site in UTM coordinate system

4. Sites Coordinate and Surface Velocity

The final result of the computation was the coordinate of the site obtained from simultaneous least square adjustment using GLOBK package program. The estimated coordinate and its standard deviation of epochs 2010, 2011 and 2012 with their precision and surface velocity are shown in Table 2. It depicts the precision of the estimated coordinate that is very high which ranges from 1.2 mm to 6.4 mm. In general, the precision of the Y-coordinate component, which is representative of the high component of the cartesian coordinate system in

Indonesian area, is always lower than the X and Z components. This condition also occurs for the daily coordinate results discussed above.

Table 2. Estimated Coordinate and surface velocity of the sites with their STD for the period of 2010, 2011 and 2012.

No	Site	Coord. (m)	STD (m)	Coord. (m)	STD (m)	Coord. (m)	STD (m)	Velocity	STD
1	CCIR_x	-2016413,154	0,00223	-2016413,2	0,00234	-2016413,175	0,00235	-0,0208	0,00227
2	CCIR_y	6005201,488	0,00541	6005201,48	0,00566	6005201,47	0,00548	-0,0143	0,00523
3	CCIR_z	-740970,496	0,0014	-740970,5	0,00149	-740970,5074	0,00144	-0,0124	0,00139
4	CPBL_x	-2097397,932	0,00232	-2097397,9	0,00245	-2097397,954	0,0026	-0,0242	0,00245
5	CPBL_y	5967772,118	0,00519	5967772,12	0,00545	5967772,102	0,00536	-0,0148	0,0051
6	CPBL_z	-814771,6662	0,00147	-814771,67	0,00153	-814771,678	0,00159	-0,0124	0,0015
7	CPKL_x	-2131462,177	0,00222	-2131462,2	0,00248	-2131462,178	0,00237	-0,0011	0,00229
8	CPKL_y	5962962,15	0,00468	5962962,15	0,00517	5962962,076	0,00477	-0,0732	0,0046
9	CPKL_z	-759735,3243	0,00131	-759735,33	0,00143	-759735,3252	0,0014	-0,0009	0,00134
10	CSEM_x	-2204462,321	0,00222	-2204462,3	0,00225	-2204462,342	0,00235	-0,0211	0,00224
11	CSEM_y	5934931,575	0,00436	5934931,58	0,00443	5934931,559	0,00447	-0,0151	0,00425
12	CSEM_z	-770741,3493	0,00123	-770741,35	0,00126	-770741,3589	0,00133	-0,0092	0,00126
13	CMGL_x	-2185668,447	0,00242	-2185668,4	0,00257	-2185668,478	0,00254	-0,0315	0,00244
14	CMGL_y	5935038,746	0,0052	5935038,75	0,00548	5935038,743	0,00513	-0,0021	0,00494
15	CMGL_z	-824386,578	0,00146	-824386,58	0,00153	-824386,5898	0,00152	-0,0122	0,00145
16	JOGS_x	-2191895,114	0,00297	-2191895,1	0,00291	-2191895,144	0,00269	-0,03	0,00266
17	JOGS_y	5927112,449	0,00641	5927112,45	0,00625	5927112,437	0,00566	-0,0112	0,00556
18	JOGS_z	-861716,4863	0,00166	-861716,49	0,00163	-861716,4945	0,0015	-0,0088	0,00148
19	CPWD_x	-2259496,548	0,00242	-2259496,6	0,00254	-2259496,569	0,00573	-0,0212	0,00437
20	CPWD_y	5912637,413	0,00544	5912637,41	0,00556	5912637,399	0,01355	-0,0113	0,01016
21	CPWD_z	-782686,1859	0,00142	-782686,19	0,00149	-782686,1921	0,00334	-0,006	0,00254

Further, the surface velocity was computed based on the coordinate differences between period of 2010, 2011 and 2012. The surface velocity ranges from 0.6 to 7.3 mm/year with standard deviation of 0.1 to 1 mm. The fastest surface velocity occurs at PKL site in the y or high component. In order to easily understand the magnitude and the direction of sites movement, the plot of surface velocity in horizontal direction was developed and shown in Figure 3. It shows that the sites move in the same direction, i.e. to the east, as an effect of the movement of the Eurasian and indo-Australian plate that meet in the this area.

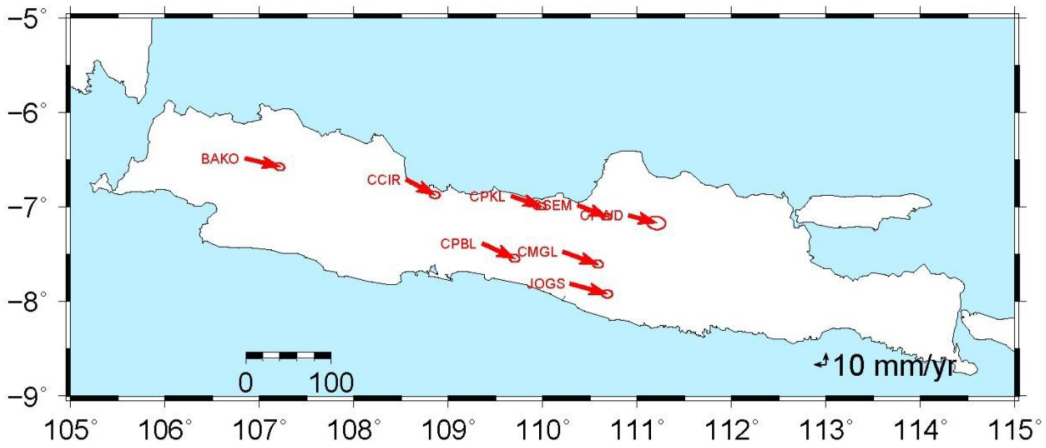

Fig. 3. The plot of surface velocity in horizontal direction.

Acknowledgement

We acknowledge Geospatial Information Agency of Indonesia for the GNSS data as the part of study of Definition of Indonesian Datum 2013.

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