AUSPOS ON-LINE GPS DATA PROCESSING IN DETECTING CRUSTAL DISPLACEMENTS DUE TO 2005 NIAS EARTHQUAKE

Agustan
Center for Natural Resources Inventory Technology
Agency for the Assessment and Application of Technology (PTISDA-BPPT), Indonesia

Abstract

The development of on-line GPS data processing nowadays is promising to be used. Therefore, it is necessary to assess the on-line GPS data processing by comparing the results to scientific GPS data processing. The 8.7Mw earthquake on 28th March 2005 in Nias Island displaced northern part of Sumatra Island. It includes small islands in the western part of Sumatra. To detect these displacements, GPS campaigns have been conducted in Simeulue Island, Nias Island and Siberut Island. These GPS data are processed by using AUSPOS facilities. A root mean square (RMS) is used as a quality indicator in GPS data processing. The results show that on-line GPS processing can be used as a tool to process GPS data to detect crustal displacements due to a big earthquake.

INTRODUCTION

The 2004 Great Sumatra-Andaman Earthquake is believed to be the trigger of 2005 Nias Earthquake. These two events caused big crustal displacements in surrounding areas, which could be measured by comparing the site coordinates before and after the event. One method to obtain the precise coordinates is by processing GPS data from GPS observation. One purpose of GPS data processing is to achieve an optimal solution for determining coordinates of point locations from some control points. In this term, optimal solution means a high accuracy in data processing.

The GPS data processing for high precision usually uses specific software that can handle specific conditions. The specific software is usually software that was developed in house. It can be customized to make it more flexible and easy to modify if one wants to apply new algorithms or advanced modeling. This type of software is called scientific software that originates from developments at scientific institutions (Seeber, 1993). Examples are: Bernese, GIPSY, and GAMIT.

Usually these kinds of software are used to process GPS data for scientific research and high-level accuracy such as Bernese for determining crustal motion (e.g. Rossikopoulos *et al*., 1998; Michel *et al*., 2001; Lowry *et al*., 2001) and GIPSY for determining 3-D displacement (Scherneck *et al*., 1998). Such software usually considers many parameters which can be modified. However, the development in on-line GPS data processing enables people to process GPS data using GPS scientific software freely but in fixed parameters. This research discusses the use of on-line GPS data processing to detect crustal displacements caused by the 8.7Mw 2005 Nias Earthquake.

ON-LINE GPS DATA PROCESSING

Due to the development of internet facilities around the world, some institutions have set up web sites where GPS data can be processed free of charge. The GPS data are up-loaded to these institutions usually in RINEX format. These institutions include: National Mapping Division of GeoScience Australia (formerly AUSLIG), Jet Propulsion Laboratory (JPL, NASA, USA), and the Scripps Orbit and Permanent Array Centre (SOPAC) at the University of California, San Diego, USA. Another web-based processing engine is provided by the United States National Geodetic Survey (NGS). It is known as the Online Positioning User Service (OPUS). This engine was not included in this investigation, as it only accepts and processes GPS data gathered in the United States of America.

The aim of these institutions in setting up on-line GPS data processing is to help people obtain coordinates from GPS data precisely in minutes. For example, GeoScience Australia (AUSPOS) processes one RINEX file in five minutes. However, on-line GPS data processing only process the GPS data using limited or fixed parameter.

METHODS

In order to investigate the reliability of on-line GPS data processing for crustal displacements, GPS data are processed by using on-line GPS data

processing from GeoScience Australia. The GPS data are obtained from an international collaboration in GPS campaigns which comprise of Nagoya University, Bandung Institute of Technology, Syah Kuala University and Agency for the Assessment and Application of Technology (BPPT). Data in Siberut Island are obtained from FORSGC (Japan initiatives project to study global climate change).

The GPS campaigns are conducted in surrounding areas of 2004 Sumatra-Andaman and 2005 Nias Earthquakes epicenter. Two new points are constructed in Simeulue Island on March and re-observed on May 2005. One point in Nias Island is observed on May 2005, however, it has previous coordinates which is observed by Bakosurtanal (Indonesian National Mapping Agency). On the other hand, point in Siberut Island is observed on March 2005 and re-observed on April 2005. The receivers used are dual frequency receivers from Trimble and Ashtech. Time observation is set-up for twelve hours at least.

In general, the strategies which are applied by AUSPOS are:

1. Measurement Modeling
   a. Observable:
      i. Ionosphere corrected L1 double difference carrier phase,
      ii. Pseudo-range only used for receiver clock estimation,
      iii. Elevation cut-off 15^0,
      iv. Sampling rate 30 seconds,
      v. Weighting 1.0cm for double difference, elevation dependent 1/sin(E).
   b. Troposphere: Hopfield and Niell mapping function
   c. Satellite Antenna Phase centre calibration: Not applied
   d. Ground Antenna phase centre calibrations: Elevation-dependent phase centre corrections are applied according to the model IGS01, the NGS antenna calibrations are used when the antenna used is not a recognized IGS type. The corrections are given relative to the Dorne Margolin T antenna.
   e. Atmospheric Drag: Jachhia Model
   f. Centre of Mass Correction / Attitude: Nil
2. Orbit Modeling
   a. Earth's Gravitational (Static) Potential Model: EGM96 - degree and order 12
   b. Solid Earth Tides (Dynamic) Potential: Love Model
   c. Ocean Tide (Dynamic) Potential: Christodoulidis
   d. Third Body Perturbations: Sun, Moon and Planets. Values for physical constants - AU, Moon/Earth mass ratio, GM(moon, sun and planets) from JPL DE403 Planetary Ephemeris.
   e. Direct Solar Radiation Pressure: Rock
3. Station Position Modeling and Reference Frame
   a. Precession: IAU76/IERS96
   b. Nutation: IAU80/IERS96 (including epsilon and psi corrections)
   c. Polar Motion IGS Earth Orientation Parameters (Ultra-rapid, Rapid, Final) – apriori
   d. Earth Rotation (UT1) IGS Earth Orientation Parameters (Ultra-rapid, Rapid, Final) – apriori
   e. Daily and Sub-daily tidal corrections to X, Y and UT1: Applied (IERS2000)
   f. Plate Motion: IGS Cumulative SSC
   g. Planetary and Lunar Ephemeris: JPL DE403
   h. Station Displacement - Solid Earth Tide Loading: Williamson and Diamante (1972) + Wahr (1980) for the frequency dependent elastic response of the Earth's fluid interior.
   i. Station Displacement - Ocean Tide Loading: not applied
   j. Station Displacement - Pole Tide: applied
   k. Station Displacement - Atmosphere Loading: not applied
   l. Reference Frame: IGS Cumulative SSC

AUSPOS also automatically selects three nearest and available GPS data from IGS stations around the observation site to perform network solution. In this research, IGS stations which are used are NTUS (Nanyang University of Technology - Singapore), COCO (Cocos Island - Australia), and BAKO (Bakosurtanal, Cibinong - Indonesia).

RESULTS

GPS data are processed in GeoScience Australia (AUSPOS) by on-line GPS processing and the results can be found in following tables.

Table 1 shows the results from AUSPOS data processing for the first observations in Cartesian-ITRF2000 except Binaka at Nias Island.

Site	X (m)	Y (m)	Z (m)	Epoch
Langi (Simeulue Island)	-638306.2480	6338336.3970	312572.2260	March 2005
Telukdalam (Simeulue Island)	-681984.4990	6334762.2750	292315.1780	March 2005
Binaka (Nias Island)	-855069.5763	6319223.3344	128903.5875	2001*
Siberut Island	-1019376.9820	6293695.0210	-174864.7550	March 2005

Table 1 The Site Coordinates before 2005 Nias Earthquake
*Binaka was observed and processed by Bakosurtanal

Table 2 shows the results from AUSPOS data processing for the second observations in Cartesian-ITRF2000.

Site	X (m)	Y (m)	Z (m)	Epoch
Langi (Simeulue Island)	-638306.0710	6338336.3390	312572.1940	May 2005
Telukdalam (Simeulue Island)	-681983.3640	6334762.8890	292314.8010	May 2005
Binaka (Nias Island)	-855067.7530	6319224.9900	128900.1350	May 2005
Siberut Island	-1019377.0200	6293694.9850	-174864.7610	April 2005

Table 2 The Site Coordinates after 2005 Nias Earthquake

The root mean square (RMS) is used as a quality indicator of GPS data processing and the results can be seen on Table 3.

Table 3 The RMS of GPS Data Processing

Site	First Campaign RMS (m)	Second Campaign RMS (m)
Langi (Simeulue Island)	0.0129	0.0125
Telukdalam (Simeulue Island)	0.0112	0.0169
Binaka (Nias Island)	-	0.0123
Siberut Island	0.0079	0.0067

To find the site displacements, all the Cartesian coordinates are transformed to Universal Transverse Mercator, WGS 1984. The results can be seen on Table 4 and Figure 1.

Table 4 The Results of Site Displacements

Site	Epoch	Northing (m)	Easting (m)	Ell. Height (m)	2-D (m)	Vertical (m)
Langi (Simeulue Is.)	March 2005	312937.7517	805822.6499	-25.7590	0.1729	-0.081
	May 2005	312937.7231	805822.4795	-25.8400		
Telukdalam (Simeulue Is.)	March 2005	292746.2349	849726.9912	-22.8610	1.2602	+0.472
	May 2005	292745.8323	849725.7966	-22.3890		
Binaka (Nias Is.)	2001	128894.2802	356030.6705	-13.7930	4.0278	+1.326
	May 2005	128890.8014	356028.6404	-12.4670		
Siberut Is.	March 2005	9825181.6534	522267.1597	-9.5150	0.0438	-0.030
	April 2005	9825181.6466	522267.2030	-9.5450		

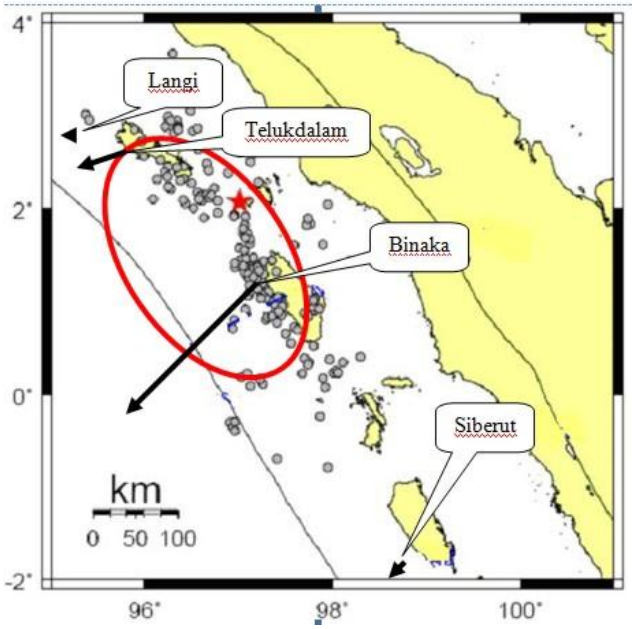

Figure 1 The Displacement of the Observation Sites

Figure 1 shows the ruptured area caused by 2005 Nias Earthquake which is marked by the red ellipse. It is determined from the uplift-submerged and displaced areas which are found after GPS data processing.

CONCLUSION

The ability of AUSPOS on-line GPS data processing to detect the crustal displacement had been assessed. The largest site displacement due to the 8.7Mw 28th March 2005 Nias Earthquake is found at Nias Island which is more than 4 meters in horizontal and uplift is more than 1 meter.

The GPS data processing strategies which are applied in AUSPOS are fixed and some of the parameters i.e. the ocean tide loading and the atmospheric loading are not applied. Therefore it is possible to obtain different solution from other GPS data processing with different strategies. It is necessary to assess the AUSPOS results with other scientific GPS data processing software to see the differences if some parameters are changed or applied.

Acknowledgements: Research Center for Seismology, Volcanology and Disaster Mitigation – Nagoya University, FORSGC-CLIVAR BPPT, GeoScience Australia, and local people in Simeulue and Nias Island.

REFERENCES

Lowry, A. R., Hamburger, M. W., Meertens, C. M. and Ramos, E. G. (2001) GPS Monitoring of Crustal Deformation at Taal Volcano, Philippines, *Journal of Volcanology and Geothermal Research*, Vol. 105, pp. 35-47.

Michel, G. W., Yu, Y. Q., Zhu, S. Y., Reigber, C., Becker, M., Reinhart, E., Simons, W., Ambrosius, B., Vigny, C., Chamot-Rooke, N., Le Pichon, X., Morgan, P. and Matheussen, S. (2001) Crustal Motion and Block Behaviour in SE-Asia from GPS Measurement, *Earth and Planetary Science Letters*, Vol. 187, pp. 239-244.

Rossikopoulos, D., Fotiou, A., Livieratos, E. and Baldi, P. (1998) A Rigorous Analysis of GPS Data To Detect Crustal Deformations. Application in the Area of The Ionian Sea, *Tectonophysics*, Vol. 294, pp. 271-280.

Scherneck, H. G., Johansson, J. M., Mitrovica, J. X. and Davis, J. L. (1998) The BIFROST Project: GPS Determined 3-D Displacement rates in Fennoscandia from 800 days of Continuous Observations in the SWEPOS Network, *Tectonophysics*, Vol. 294, pp. 305-321.

Seeber, G. (1993) *Satellite Geodesy, Foundations, Methods and Applications*, Walter de Gruyter, Berlin, 531p.