Potential Use of GPS Data for Offshore Platform Monitoring Utilizing Scientific Software

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Abstract

One of the major problems of engineering structure such as platform is the occurrence of subsidence, which may cause disaster to human being and platform itself. Implementing a subsidence monitoring system to this stability is a rational approach to addressing the safety operation of the platform. Because of its remote location, subsidence of offshore platform needs to be observed by using Global Positioning System (GPS) technique. Pulai platforms located in South China Sea and about 300 km from the shore of west Peninsular Malaysia is observed using GPS technique to detect its subsidence. The data in this case require complex modeling and specific strategies of processing in order to obtain high precision coordinate. Hence, a real subsidence can be determined without any influence of error or bias. The processing used scientific software GAMIT/GLOBK in addressing requirement for high precision. This paper presents the preliminary investigation of processing GPS data of Pulai offshore. The result reveals that there were different values of the third North, East and Up coordinates from the solution in two epoch's observation.

Keywords
GPS data, offshore platform, scientific software

1. Introduction

Determination of subsidence of offshore platform can be done with either geotechnical, structural or geodetic method (Setan, 2006). By using geodetic approach, the GPS technique will give beneficial in enable to carry out subsidence monitoring since the platforms are located hundreds of kilometers from shore. This technique can be used to measure without conventional method and require minimum user interface. The other advantage is because of its precise coordinate in 3-dimensional data which is resulted at relative high speed in any weather condition. The flowchart in Figure 1 elaborates the two epochs GPS observation for subsidence.

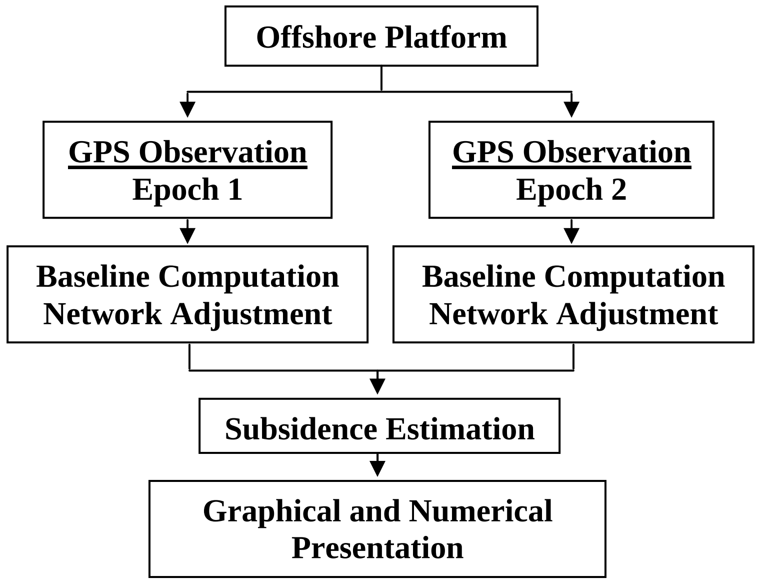


Figure 1: Flowchart of subsidence observation

GPS data for subsidence monitoring require complicated modeling and particular approach in order to find a really subsidence without any effect on error or bias. Prior to this work on the offshore platform, processing is supposed to utilize scientific software addressed for high precision.

Pulai offshore platform is necessary to be observed in term its subsidence monitoring for supporting its operation in safety manner. In order to obtain precise result, the processing of this GPS data implements the GAMIT/GLOBK software to determine coordinate and its precision. This software has been developed for precise positioning purpose, offering many options to reduce errors in the baseline processing.

2. Relative Positioning GPS

The fundamental theory of unstable object monitoring is to apply GPS relative positioning referred to the more stable control station. A number of control stations between reference station (i.e. control points on shore) and object station (i.e. control points on offshore platforms) need to be established for measurement in term of baseline vectors (Δx, Δy, Δz). With the purpose for detecting of offshore platforms subsidence, GPS is considered as the suitable instrument to determine relative position between reference stations. This is due to reach a high precision that essential for subsidence monitoring (Leick, 2004; Setan, 2006).

The relative positioning technique (Figure 2) involves of control point on shore (station P) and control point established at the offshore platform (station Q). The relative static GPS observations are carried out for 24 hours to give the required precision for a long baseline. The GPS relative positioning is carried out to determine the coordinates of an unknown point with respect to a known point. This technique requires at least two receivers, one as the reference station and the other as the object station. Both receivers observe the same satellite to collect the observation data at both stations then used to estimate the position of the object station, relative to the reference station.

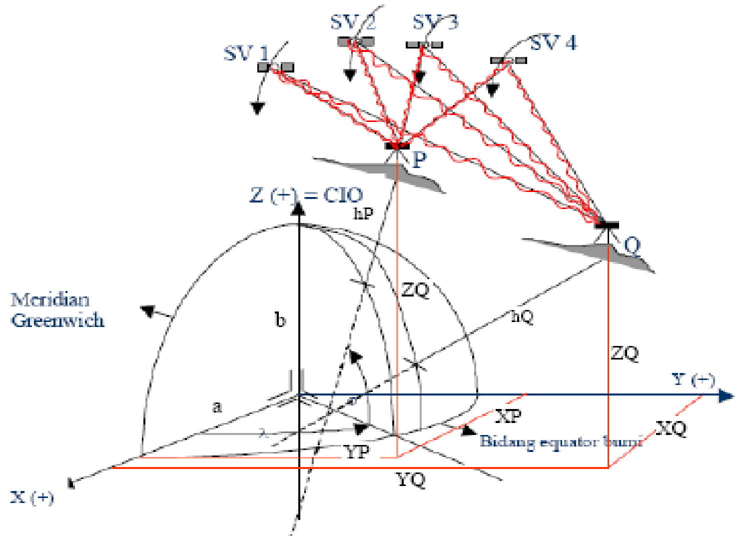


Figure 2: Relative positioning using GPS technique (Abidin, 2000)

3. GAMIT/GLOBK Software

GAMIT content of series of program that analyze GPS phase data to estimate parameters: station positions (coordinates), satellite orbital parameters (initial conditions, radiation parameters, phase center offsets), Earth Orientation Parameter (EOP), atmospheric delay parameters (time-dependent Zenith delays and gradients), carrier phase ambiguities, (Herring, et al., 2006). GAMIT is categorized as scientific software tends to have been built up by Massachusetts Institute of Technology, USA for research and precise positioning purpose.

GAMIT estimate the relative positions of a set of stations and the other parameter by fitting to doubly-differenced phase observation by using a weighted least squares algorithm. These stations generally take in well spaced permanent site within a global network such as International GPS Service (IGS). The user is able to insist on different constraints on each station coordinates in the solution. Usually the known and unknown stations are tightly and loosely constrained, respectively (Lestari, 2006). After new coordinates of the unknown stations are found in the processing, a priori coordinates can be renewed by tightened constraints.

GAMIT generates the solution with only loose constraints on the parameters. Therefore, in order to avoid any bias of the combination, last GLOBK stage defines the reference frame by imposing constraints on stations' coordinates (Dong., et al., 1998). GLOBK is software with Kalman filter algorithm which main principle is to combine solutions of the processing of primary data from space-geodetic or terrestrial observations. It accepts as data the estimated and associated covariance matrices for station coordinates and the other parameter generated from analyses of the primary observations. These principal solutions should be performed with loose a priori uncertainties assigned to the global parameters, so that the constraints can be applied uniformly in the combined solution (Herring, et al., 2006).

4. Data Observation

The GPS observations were performed during the eight days in the first and second epoch using Trimble 4000 SSI Geodetic series GPS receiver. Each session was planned as a period of 24 hours continuously on a daily basis. The recording interval was 15 second with at least 10° mask-angles of configuration. Surveys campaign was carried out by Fugro Geodetic (Malaysia) Sdn Bhd (Report on Platform Subsidence Surveys, 2003). Processing utilized eight days Pulai GPS (rinex) data in both epochs. Figure 3 shows the schematic scenario of computation.

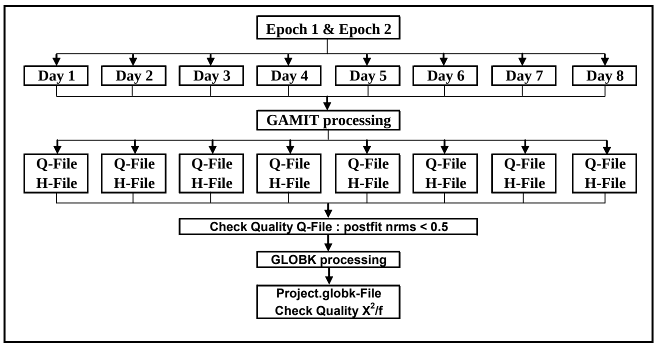
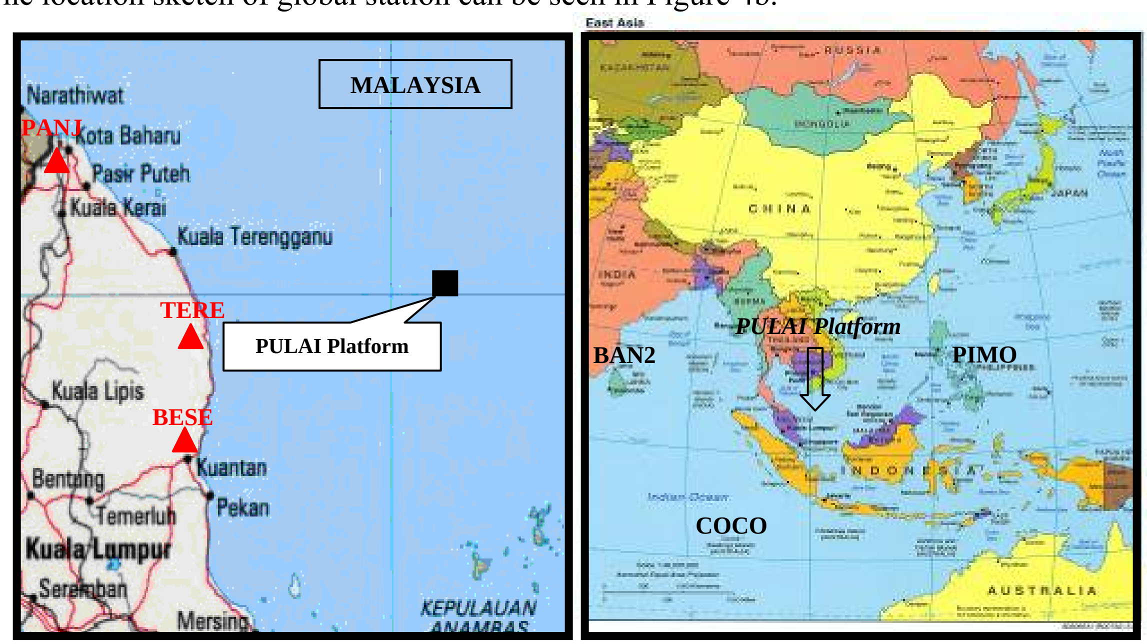


Figure 3: Scenario of Pulai platform computation

The network configuration is illustrated in Figure 4a with Pulai offshore platform and some Malaysian Primary GPS station such as BESE (Beserah-Kuantan), TERE (Kuala Terengganu) and PANJ (Rantau Panjang). The processing applies Pulai as an object station and Malaysian primary GPS as a regional reference station. Besides, the processing also uses some global reference station IGS such as PIMO (Philippines), COCO (Australia) and BAN2 (India). The IGS rinex GPS and precise ephemeris data downloaded from IGS web. The location sketch of global station can be seen in Figure 4b.



(a) Malaysian primary GPS stations (b) Global station from IGS

Figure 4: Sketch of station configuration (http://www.lib.utexas.edu)

5. GAMIT/GLOBK Processing

The processing of the GPS data used the GAMIT software to generate daily solution. Then, these solution were combined in order to find station coordinates in the reference frame by using GLOBK software (Herring, et al., 2006).

Some softwares prepared for GPS data processing are Fedora Core with Linux Operating System and TEQC software organize three main functions namely translating, editing, and quality checking file rinex. NetCDF (Network Common Data Form) set up for interface in sharing and transfering acces of scientificly data especially in preparing of interface C, Fortran-77 and Fortran-90 for GAMIT instalation. GMT (Generic Mapping Tools) put in order to data plotting of GAMIT output and finally GAMIT/GLOBK software installed for data processing.

GAMIT procedure has special structure of working directory. Input data is done by entering every data to working directories. These are /project for the name of project, /doy for the result of processing, /rinex for saving rinex observation file, /brdc for saving rinex navigation file, /tables for saving of links referred to some files at /usr/local/gamit/tables directory and /igs for saving precise ephemeris file downloaded from IGS web.

After preparing these working directories, all files are located at the appropriate directory. Initial file such as L-file., station.info, sestbl., sittbl., autcln.cmd should be arranged in /tables directory. Establishing of link directory is main part in GAMIT processing step. Under home user (/home/user) directory is completed a link to GAMIT directory namely gg directory. Function of the link made easier GAMIT access from working directory to GAMIT system directory. From /tables directory is utilized links.tables command to compose a link related /tables from working directory to GAMIT system directory. The link is also done from /doy directory by using links.day command with the intention that having a link to file at /tables directory. From /doy directory is also prepared a link relayed to /rinex, /brdc, /igs directories. The command to create a link from /doy to /rinex directory apply sh_link_rinex1 –year <yyyy> -day <doy> -dir <directory rinex> command. The link rinex command is employed to build a link to /rinex directory and scan to rinex data. –year and -day option is exercised to filtering in order that the link is only data which will be computed. -dir option is brought into play to deliver to source or rinex data directories.

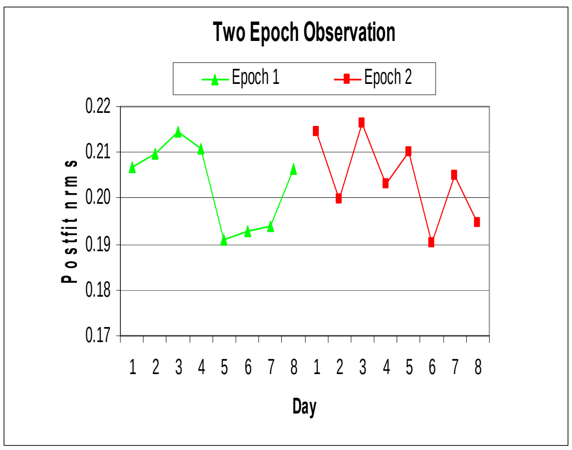
The procedure of data processing use GAMIT software consist four components such as makexp, makex, fixdrv, batch processing. Each component is processed in sequence. Then GAMIT ought to perform several modules in serially running, namely ARC, YAWTAB, MODEL, AUTCLN, CFMRG, SOLVE, MODEL, AUTCLN, CFMRG, sh_sigelv and SOLVE. The last output Q-file of executing SOLVE program is “a” Q-file serial. The file contains all solutions of GAMIT processing.

The main output of GAMIT is a loosely constrained solution (H-file) of estimated parameter and variance-covariance information which pass to GLOBK for combination of data to estimate station position (Popovas, 2001). In order to get a time series from quasi observation (the estimated and associated variance-covariance matrices for station coordinates and the other parameter generated during the analysis of the primary observations), four menus namely HTOGLB, GLRED, GLOBK,GLORG steps is applied in the processing.

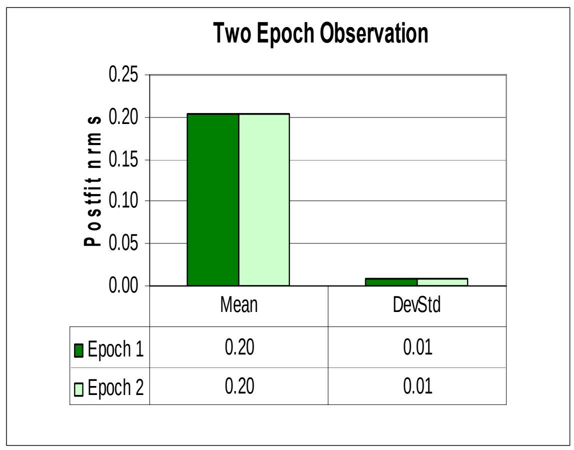
6. Result and Discussion

The number of station at each daily processing is not the same on one epoch's observation. For example, there are POP1, POP2, POP3, Malaysian primary and IGS station for first day and POP4, POP5, POP6, Malaysian primary and IGS station for seventh day. On the other hand, there are POP1 to POP6, Malaysian primary and IGS station for sixth day. The scenario of data processing in each day depends on the available GPS data. The following section is the preliminary result of GAMIT/GLOBK processing.

The primary indicator of GAMIT solution for determining an acceptable solution is the normalized root mean square (nrms) i.e., the square root of chi-square per degree of freedom. Usually with the default weighting scheme, a good solution produce an nrms of about 0.25 (Herring, et al., 2006). Figure 5a shows the nrms of the daily GAMIT solution in both epochs from the Q-file output. The result illustrates the nrms about 0.2 and the number for each day processing is very close. It means that there are high quality data, the error randomly distributed and the corrected of station apriori weight. Furthermore there are no serious modeling problems apparent since the nrms is relatively small and less than 0.25 which is considered to be a good high ionosphere and solution procedures. The graph in Figure 5b depicts standard deviation and mean of postfit nrms in each epoch. There are same value of mean (0.02) and standard deviation (0.01) for both epochs processing.



(a) Postfit nrms



(b) Mean and standard deviation

Figure 5: Primary indicator of daily GAMIT processing

The primary quality assurance statistic of GLOBK solution is χ^2/f, the chi-squared increment per degree of freedom. Table 1 shows the χ^2/f of daily and global processing from GLOBK output. The global processing is run by arrangement all daily solutions. Shown in this table, the individual values never exceeded 3.0, indicating that each of the campaigns is internally and externally consistent (Lestari, 2003).

The H-file associate with each day in the campaign is combined together using GLOBK. Table 2 shows the estimated coordinate of the Pulai station from GLOBK solution in the local system with the horizontal component North (N) and East (E), and the vertical component (U). The N, E and U are the products of the adjustment in geodetic latitude, longitude and height respectively.

Table 1: χ^2/f of daily and global processing from GLOBK output

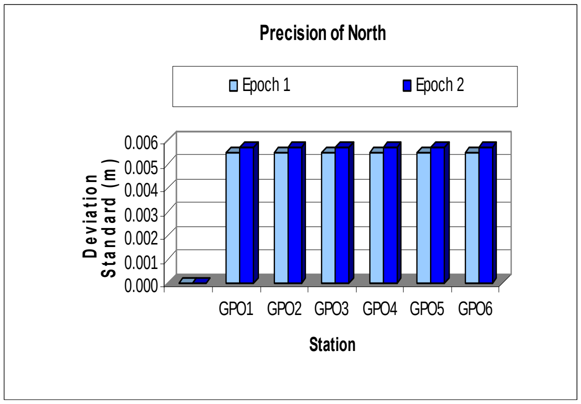
Epoch 1									
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**global**
χ^2/f	0.559	0.433	0.460	0.393	0.151	0.356	0.469	0.739	0.559
Epoch 2									
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**global**
χ^2/f	0.564	0.461	0.446	0.463	0.571	0.597	0.277	0.725	0.564

Table 2: Estimated coordinate in local system

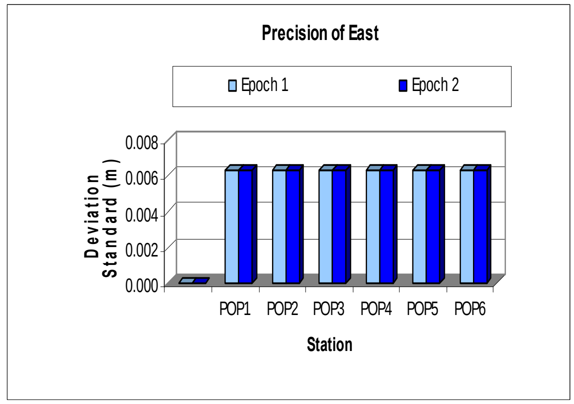
Station		Epoch 1	Epoch 2
POP1	North (m)	593207.89048	593207.89252
	East (m)	11692467.77280	11692467.77186
	Up (m)	38.33709	38.34215
POP2	North (m)	593181.00329	593181.00532
	East (m)	11692463.03050	11692463.02954
	Up (m)	38.21389	38.21905
POP3	North (m)	593223.52963	593223.53160
	East (m)	11692414.83895	11692414.83799
	Up (m)	38.86396	38.86909
POP4	North (m)	593494.33501	593494.33695
	East (m)	11691033.58071	11691033.57984
	Up (m)	31.65036	31.65561
POP5	North (m)	593481.51627	593481.51835
	East (m)	11691021.59806	11691021.59712
	Up (m)	31.68752	31.69202
POP6	North (m)	593510.39778	593510.39973
	East (m)	11690987.08630	11690987.08537
	Up (m)	27.93186	27.93700

Table 2 shows the N, E and U estimated coordinate in meter of the six object stations for first and second epoch processing. Station POP1 to POP6 located on the offshore platform.

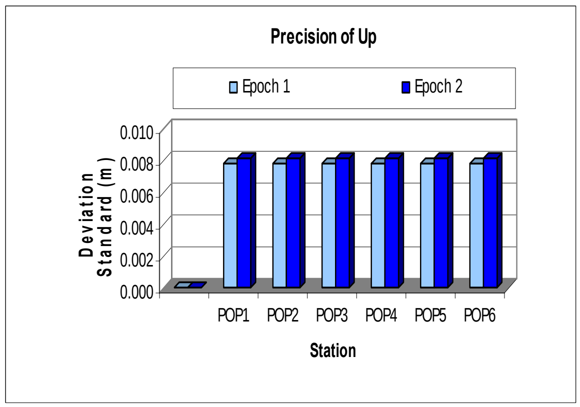
Figure 6a, 6b and 6c in a series are the precision of N, E and U. These figures indicate a little bit differences standard deviation between both epochs processing. The horizontal component (N and E) have similar precision of 5 to 6 millimeters. The vertical component (U) has poorer precision than the horizontal component, here about 8 millimeters. The precision of six stations of two epochs processing are similar for horizontal and vertical component.



(a) North



(b) East



(c) Up

Figure 6: Standard deviation of N, E and U coordinate

Table 3: Coordinate differences

Station	POP1	POP2	POP3	POP4	POP5	POP6
	Difference					
North (m)	-0.00204	-0.00203	-0.00197	-0.00194	-0.00208	-0.00195
East (m)	0.00094	0.00096	0.00096	0.00087	0.00094	0.00093
Up (m)	-0.00506	-0.00516	-0.00513	-0.00525	-0.00450	-0.00514

Table 3 depicts the coordinate difference for station POP1 to POP6 between both epochs. Shown in this table, there is a slightly difference value in third N, E and U. The difference of N, E and U is about 2, 1 and 5 millimeters respectively. The biggest of N is 2.08 millimeters for station POP8 and the smallest is 1.94 millimeters for station POP4. There are maximum 0.96 millimeters and minimum 0.87 millimeters for E. The U difference is 4.50 millimeters as smallest and 5.25 millimeters as biggest value.

As can be seen in Figure 5, the precision of horizontal components are around 5 millimeters and vertical component is about 7 millimeters. It should be smaller than this number, since the processing used L1 and L2 data and apply algorithm which can eliminate systematic error. This phenomenon is suspected occur due to any influenced outliers to the result. The next future work should be continued by proving the quality of all daily solution by executing a daily stochastic run using the GLRED module. The stochastically verified values are plotted as a time series using the GMT software along trend and precision information. From this plot outliers in the data could be easily seen.

There are two possible alternatives can be carried out, when outlier is found (Lestari, 2006). The first is to repeat the processing of the primary observations for certain days (e.g. using GAMIT). This step will be performed by presuming that editing or model changes will increase the precision. The second option is to eliminate the H-files from these days for further analysis. This second approach will use with assumption that there are unknown or unmoveable effects in the data. The most likely effects are that the antenna was bumped and the network or the satellite geometry was changed.

7. Closing Mark

Based on the result of data processing, it can be inferred that the precision of horizontal and vertical component is around 5 and 7 millimeters respectively. This result is suspected due to any influenced outlier. It is occurred because the proving of the quality of all daily solution by executing a daily stochastic step has not been established yet.

Nevertheless, the usage of GPS technique for platform's subsidence monitoring can be implemented with some appropriate consideration in choosing a receiver GPS instrument (capability, precision requirement, level noise of antenna, etc.) applying a particular strategy in both observation (duration, mask-angle, recording interval, etc.) and processing (check quality data, remove error and bias, resolve any ambiguity, etc.).

This several option is used as an input parameter in determining strategy of processing in GAMIT/GLOBK. Therefore, utilizing this software for processing GPS data for subsidence monitoring is applicable, because of the capability in achieving high precision coordinate. Hence, the platform subsidence can be monitored as an effort in increasing the safety and life-time of a platform.

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