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ASSESSMENT OF A COST-EFFECTIVE GPS DATA PROCESSING ALTERNATIVE IN EGYPT UTILIZING INTERNATIONAL ON-LINE PROCESSING SERVICES

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Abstract

River Nile is one of the natural rivers that are subjected to erosion and sedimentation and accordingly to the change of its bed levels and contours. These changes in bed levels may affect different river usages and characteristics such as navigation, bank stability and morphology. Nile research Institute (NRI) is performing a continuous river hydrographic and topographic survey starting from 1979 up till recent survey of the river (on going now). The recent maps are now produced by NRI in cooperation with the Egyptian Survey Authority using the most advanced techniques of Global Positioning Systems (GPS).

Over the last few years, a number of free of charge on-line GPS processing services have been established and being available over the Internet. In order to judge two of these processing services; namely the PPP and AUSPOS services, static GPS observations that have been collected over 10 national GPS stations have been uploaded to both websites. The attained results show that the PPP service produces 3D standard deviations that have a mean of 0.090 m, and an accuracy average, when compared to the published coordinates, equals 0.209 m. Similarly, the accomplished outcomes of the AUSPOS service yield standard deviations with a mean of 0.026 m, and an accuracy average equals 0.240 m in the 3D space. Concerning the differences to the ESA stations' coordinates, the comparison reveals that the PPP results are better than the AUSPOS results by approximately 13%.

Investigating the on-line GPS processing services demonstrates several merits: (1) they are free of charge, (2) there is no need to purchase a processing software package, (3) those services are very useful for beginners GPS users who do not have a great experience in GPS processing strategies; and (4) using IGS stations to tie local GPS networks implies that receivers over base stations are not needed to be deployed in the field campaigns, and hence the time needed to collect data is considerably reduced. These advantages yield a substantial cost-saving in GPS surveying and mapping projects, and thus, on-line GPS processing services are recommended to be employed particularly for GPS campaigns in national development projects in Egypt.

1. Introduction

The Global Positioning Systems (GPS) is forming an essential tool for hydrographic and topographic survey for the River Nile and its banks. Nile Research Institute (NRI) has used this tool to develop the topographic and hydrographic maps to River Nile and its two branches with a total length of 1440 Km. The hydrographic survey for the River Nile and the topographic survey for River Nile banks are performed using GPS. Moreover, the hydrographic survey of Lake Nasser is performed by GPS since 1998 till now. Nile Research Institute has formed a huge data base of topographic and hydrographic GPS data (NRI, 2006).

Increasingly the spatial information sector is turning to the Internet as a tool to aid their activities. Both public and private sector organizations are developing, promoting and delivering their services and products using the Internet as a medium. Recently, several international organizations have developed on-line Global Positioning System (GPS) processing services. These services receive the user GPS observation files, in the RINEX format, and return back processing results free of charge. Organizations that provide these free services include: Geo-hazards Division of Geo-science of Australia, the Geodetic Survey Division (GSD) in Canada, the United States' National Geodetic Survey (NGS), Scripps Orbit and Permanent Array Center (SOPAC) at the University of California; and the Jet Propulsion Laboratory (JPL) at the US National Aeronautics and Space Administration (NASA).

The objective of this research study is to evaluate some of these online services, based on real GPS data, and compare their position results with expected values, as published by the Egyptian Survey Authority (ESA), in order to highlights the benefits of those international services particularly for surveying and mapping activities in Egypt. A brief description of each processing service is presented in section 2, while section 3 supplies the results of similar studies that have been carried out worldwide. Section 4 describes the available GPS data set that has been utilized to judge two of these on-line processing services. The achieved results are presented in section 5, and the concluded remarks are given in section 6.

2. Overview of online GPS processing services

There are a number of online GPS processing services that provide GPS processing results to the user free of charge and with unlimited access. These services provide solutions for a user-submitted Receiver Independent Exchange Format (RINEX) file based on differential methods using reference stations or precise point positioning using precise GPS orbit and clock data. Organizations that provide these free services include: Geohazards Division of Geoscience Australia, the Geodetic Survey Division (GSD) in Canada, the United States' National Geodetic Survey (NGS), Scripps Orbit and Permanent Array Center (SOPAC) at the University of California and the Jet Propulsion Laboratory (JPL) at National Aeronautics and Space Administration (NASA). An overview and a brief comparison are presented, herein, for a number of these global services [For more details, refer to Dare, 2006].

AUSPOS Service

The Geo-science Australia [formerly the Australian Surveying and Land Information Group's (AUSLIG)] Online GPS Processing Service (AUSPOS) was officially launched in late 2000, and has been in continuous operation since then processing data for dual frequency geodetic GPS receivers located anywhere on earth. AUSPOS was designed and implemented with the following features and design goals: an easy to use web page interface, dual frequency geodetic GPS data processing capability, standard web-browser direct upload or ftp, highest quality global GPS processing standards, 24 hour 7 days a week service, rapid processing turnaround, < 15 minutes/file, results returned by email and ftp server, applicable anywhere on Earth; and GDA94 compliant for Australian users, ITRF elsewhere. The AUSPOS positioning is by differential GPS to the nearest three International GNSS Service (IGS) stations and uses the IGS precise orbit information. The AUSPOS design facilitates its use for a variety of applications, including: DGPS reference station positioning, remote GPS station positioning, ultra-long baseline positioning, GPS connections to IGS stations, high accuracy positioning; and GPS network quality control. This service is accessible via the Geo-science Australia website at: http://www.ga.gov.au.

PPP Service

The Geodetic Survey Division (GSD), Canada, developed the Canadian Spatial Reference System (CSRS) Precise Point Positioning (PPP) service. The PPP service provides post-processed position estimates over the Internet from GPS observation files submitted by the user. Precise position estimates are referred to the North American Datum of 1983 as well as the International Terrestrial Reference Frame (ITRF). Single station position estimates are computed for users operating in static or kinematic modes using precise GPS orbits and clocks. The online PPP positioning service is designed to minimize user interaction while providing the best possible solution for the given observation availability. Users need only specify the mode of processing, static or kinematic, and the reference frame for position output, NAD83 or ITRF. The observations processed are selected from the submitted RINEX file in the following order: (a) L1 and L2 pseudo-range and carrier phase observations, (b) L1 pseudo-range observation. Compared to uncorrected point positioning using broadcast GPS orbits, this application can improve results by a factor of 2 to 100, depending on user equipment, dynamics and duration of the observing session. This service is available via the GSD website at: http://www.geod.nrcan.gc.ca.

SCOUT Service

The Scripps Coordinate Update Tool (SCOUT) was developed by the Scripps Orbit and Permanent Array Center (SOPAC). This service also uses by default the three nearest IGS stations. However, this service allows the user to choose up to four different reference stations. The service’s website is: http://sopac.ucsd.edu/

OPUS Service

The United States’ National Geodetic Survey developed the Online Positioning User Service (OPUS). This service generates coordinate results by using data from three Continuously Operating Reference Stations (CORS). The CORS sites are chosen not according to closest proximity but picked according to compatibility between the user’s data and the CORS site. There is also an option that allows the user to choose the CORS stations to be used. The service can be found at: http://www.ngs.noaa.gov.

Auto-GIPSY Service

Auto-GIPSY is an e-mail/FTP interface to the GPS Inferred Positioning System (GIPSY) developed by JPL. This service performs single point positioning, and is therefore not dependent on the proximity or availability of CORS/IGS data. The FTP address of user's data should be submitted by email to: ag@cobra.jpl.nasa.gov. For more details, visit the service's website at: http://milhouse.jpl.nasa.gov/ag/

A comparison of online services

There are general factors to consider in the evaluation of services; these include: the method of sending and receiving the data, the time delay in receiving the results; available options and limitations. An overall assessment of each service (summarizing the above-mentioned aspects) can be seen in Table 1. As can be seen in Table 1, the services use either uploading of the data or an FTP site in order to access the user's RINEX file. However, all of the services send an e-mail to the user either including the results or the FTP address of where the results can be obtained. Time delay on receiving the results depends on several factors including the traffic on the Internet and the number of users accessing the service at the same time. The displayed times in the Fourth column of Table 1 are only a rough indicator in order to compare the speed of each service and were obtained by submitting the same 6-h data set to each service [Dare, 2006].

3. Results of previous studies

In order to build a clear outlook about on-line GPS processing services and their merits, results of several research studies are presented herein. Soler, et al. [2006] have processed 30 consecutive days of GPS data using the OPUS service to determine how the accuracy of derived three-dimensional positional coordinates depends on the length of the observing session, ranging from 1 to 4 hours, over five Continuously Operating Reference Stations (CORS). The results emphasis that recommended session time for static data should be with a minimum of 2 hours in order to obtain a root mean square error better than five centimeters. Additionally, Witchayangkoon [2000] has investigated the accuracy of the precise point positioning (PPP) approach utilizing six-hour dual-frequency GPS data sets from four stations. It has been found the static solutions agree to within 10 cm with published coordinates, while the kinematic solutions show a discrepancy of less than one meter, mostly around half a meter. Moreover, Featherstone and Dent [2002] have performed a similar study utilizing the AUSPOS service in order to use this web-based service, along with a geoid model for Australia, to obtain orthometric heights utilizing only one GPS receiver. They have found that the computed coordinates of the check points differ from the published values by a total (geodesic) distance of 63 mm.

Furthermore, new modifications of the current processing models and strategies are being carried out in order to achieve more accurate results from such on-line services. For example, Chen et al. [2006] have analyzed the contribution of all major errors in the PPP observation models to the positioning accuracy and have developed new programs for static and kinematic PPP data processing. A new PPP algorithm based on parameter elimination method which separates time-variable parameters (i.e. position coordinates and receiver clock) and ambiguity and tropospheric delays has been proposed for data processing. The positioning accuracy of 1 cm has been achieved with this static PPP method after the solution converges.

4. Utilized national GPS data

The available GPS data set consists of dual-frequency static GPS observation files that have been collected over 10 national GPS networks established by the Egyptian Survey Authority (ESA). This data set, depicted in Figure 1, has been observed by the Nile Research Institute (NRI) within the activities of the pioneer project for updating the topographic and hydrographic maps of the Nile River. The study area covers the region that extends in the North-South direction from $22^{o}\ 25^{'}$ N to $31^{o}\ 12^{'}$ N, and extends in the East-West direction from $30^{o}\ 37^{'}$ E to $31^{o}\ 34^{'}$ E. Those GPS observations have been used to tie the new established GPS Nile networks to the national GPS frame in order to assure the integrity of the achieved maps. The utilized GPS sessions, observed during the period 2002-2004, span a time ranging from 2.7 to 6.2 hours with an average of 3.8 hours.

5. Processing and results

Two of the previously mentioned on-line GPS processing services have been selected to deal with. The Canadian PPP and the Australian AUSPOS services are chosen due to two reasons: (1) PPP represents a category of services that is based on utilizing precise IGS GPS satellites orbits and clock corrections to estimate precise coordinates of the needed stations, while the AUSPOS is a candidate of the second category where, in addition, the IGS stations are used to tie the new ones in the ITRF2000 reference frame, (2) Both services are easy-to-use with minimum user interface needed, and based on upload the RINEX files instantaneously to the service website.

It worth to mention that the users of these on-line GPS processing services should be aware of a significant feature, that might lead to inaccurate results. Although the information on the antenna height and type are included in the RINEX files, the users must enter this piece of information in the appropriate website fields before uploading the RINEX files to the processing services. Otherwise, the antenna height will be considered as zero which, of course, will produce an error in the estimated station coordinates.

The first step in the processing stage was to convert the original GPS observation files to the RINEX format. It has been performed using the Lieca' SKI-Pro software since all the data have been collected using Lieca System 500 GPS receivers. Hence, those files have been sent to both on-line processing services. The attained processing results are presented in the following sub-sections.

5.1 Results of utilizing the PPP service

One of the merits of PPP is its richness of statistical information included in the output file. For example, it produces graphical representation of the standard deviations (SD) of each coordinate component (latitude, longitude, and geodetic height) as a function of the observation time span. Figure 2 is a typical example of such graphics for one of the utilized GPS stations. It can be seen, from this figure and other figures for all stations, that approximately forty minutes of collected satellite signals is needed to reach a centimeter level in the standard deviations. The statistics of the attained standard deviations, as a measure of precision of the ten used GPS stations, are summarized in Table 2. From this table it can be noticed that the horizontal SD vectors range from 0.018 to 0.064 m with a mean of 0.043 m, while the 3D vectors of SD range from 0.032 to 0.141 m with an average of 0.090 m.

Furthermore, the obtained coordinates of each station have been compared against their published ESA coordinates in order to estimate the accuracy of the achieved PPP results. The statistics of the attained coordinates' differences are summarized in Table 3. From this table it can be noticed that the horizontal error vectors range from 0.079 to 0.266 m with a mean of 0.190 m, while the 3D error vectors range from 0.120 to 0.268 m with an average of 0.209 m.

5.2 Results of utilizing the AUSPOS service

The same RINEX files of the available 10 dual-frequency static GPS observations have been uploaded to the AUSPOS on-line GPS processing service. As mentioned previously, AUSPOS used the nearest 3 IGS stations to tie each new station and estimates its coordinates in the ITRF2000 frame. Additionally, the AUSPOS uses the EGM96 global geopotential model to estimate the geoid undulation, and hence can compute the orthometric height of each submitted station. Details of the GPS processing parameters, presented in Appendix 1, are included in the output file of each station. The statistics of the attained standard deviations, as a measure of precision of the ten used GPS stations, are summarized in Table 4. From this table it can be noticed that the horizontal SD vectors range from 0.009 to 0.037 m with a mean of 0.024 m, while the 3D vectors of SD range from 0.011 to 0.040 m with an average of 0.026 m. These figures are close to the results of a previous research study that has been performed on a local PC processing environment, not dealing with on-line processing service, and has utilized the basics of such an approach of employing the IGS precise orbits and IGS tie stations [Dawod, 2006].

Moreover, the obtained coordinates of each station have been compared against their published ESA coordinates in order to estimate the accuracy of the achieved AUSPOS results. The statistics of the attained coordinates' differences are summarized in Table 5. From this table it can be noticed that the horizontal error vectors range from 0.183 to 0.300 m with a mean of 0.230 m, while the 3D error vectors range from 0.196 to 0.302 m with an average of 0.240 m.

5.3 An assessment of achieved results from both services

A comparison between the coordinate differences of both PPP and AUSPOS results, as compared against the ESA published values, has been performed. Table 6 presents the attained statistics, which shows that the 2D error vector between the two services' results range from 0.044 to 0.157 m with an average of 0.086 m. In the 3D space, the error vector between the two services' results range from 0.049 to 0.175 m with an average of 0.098 m. These differences are basically due to the processing strategies applied in each service. As mentioned earlier, the AUSPOS service uses the nearest three IGS stations to tie the new station and estimates its coordinates, which does not applied in the PPP service. It is a matter of fact that fixing more than one GPS station, in a GPS network adjustment, creates an over-constraints least-squares adjustment scenario which causes the accuracy of the estimated coordinates being a function of the accuracy of the fixed coordinates. Concerning the differences to the ESA stations' coordinates, the comparison reveals that the PPP results are better than the AUSPOS results by approximately 13% in the three-dimensional sense.

The results of the comparison of both services' results state that there is two key issues need further detailed investigations from the geodetic community in Egypt. Firstly, the results of some research studies, as mentioned in section 3, found that the expected accuracy results of on-line processing services are within the 10 cm level, while the achieved 3D results of the current study, when compared against the ESA coordinates, are 21 and 24 cm for the utilized two services. Unfortunately, there are no published processing details about the HARN national GPS network of Egypt. For example, it is not known, as far as the authors concerns, to which version of the ITRF reference frames the HARN coordinates are referred. The second crucial issue is the estimation of the effects of crustal movements on the GPS stations' coordinates since the establishment of the HARN network in 1995. Badawy [2005] has investigated present-day seismicity and crustal deformation of Egypt based on a comprehensive earthquake catalog from 1900 to 2004 by focal mechanism stress inversion and by recent GPS observations. He has found that the average horizontal velocity of GPS stations in Egypt is 5.15 ± 1.1 mm/year in mostly NNW direction. El-Fiky [2005] has analyzed five GPS measurements collected in campaign mode during the period 1997-2002 in order to derive velocity vectors and principal components of crustal strains along the Gulf of Suez and in the southern part of the Sinai Peninsula, Egypt. He has estimated horizontal velocity vectors, of this region, in the ITRF2000 reference frame in the range of 29-35 mm/yr. Additionally, analyzing the GPS-derived velocity field, over 1988–2005, for the zone of interaction of the Arabian, African, and Eurasian plates indicates counterclockwise rotation relative to Eurasia at rates in the range of 20–30 mm/yr [Reilinger, et al, 2006]. Hence, it is recommended that these two issues and their effects of the Egyptian national GPS HARN stations' coordinates should be investigated in details.

6. Conclusion

Recently, a number of on-line GPS processing services that provide GPS processing results to the user free of charge have been established. An overview and a brief comparison have been presented for a number of these global services. Dual-frequency static GPS observation that have been collected over 10 national GPS networks have been used to assist two of these processing services; namely the Canadian PPP and the Australian AUSPOS.

The attained results show that the PPP service produces horizontal standard deviations, as a measure of precision, that have a mean of 0.043 m, while the 3D average value is 0.090 m. Additionally, the accuracy of the achieved PPP results, when compared against the ESA published coordinates, show a mean of 0.190 m in the 2D sense and an average of 0.209 m in the 3D space. Similarly, the accomplished outcomes of the AUSPOS service yield horizontal standard deviations with a mean of 0.024 m, while the 3D average value is 0.026 m. Also, the accuracy of the achieved AUSPOS results, when judged against the ESA coordinates, reveal a mean of 0.230 m in the 2D sense and an average of 0.240 m in the 3D space. Concerning the differences to the ESA stations' coordinates, the comparison reveals that the PPP results are better than the AUSPOS results by approximately 13% in the three-dimensional sense. The achieved findings, also, recommend that further detail investigations should be carried out specifically on the effects of crustal deformations on the Egyptian national GPS HARN stations' coordinates.

The main merits of on-line GPS processing services available over the Internet are: (1) they are free of charge, (2) there is no need to purchase a processing software package, (3) those services are very useful for beginners GPS users who do not have a great experience in GPS processing strategies; and (4) using IGS stations to tie local GPS networks imply that base stations are not needed to be deployed in the field campaigns. These advantages yield a significant cost-reduction in GPS surveying and mapping projects, and hence, on-line GPS processing services are recommended to be utilized particularly for GPS campaigns in national development projects in Egypt.

References

Badawy, A., 2005, Present-day seismicity, stress field and crustal deformation of Egypt, Journal of Seismology, V. 9, No. 3, pp. 267-276.

Chen W, Chen Y, and Ding X, 2006, GNSS applications in Deformation monitoring, Intelligent transport systems, Precise Point Positioning and Atmosphere study, GIS Development, June Issue, (http://www.gisdevelopment.net/magazine/years/2006/june/38_1.htm).

Dare P., 2006, Online GPS processing services: an initial study, GPS Solutions, No. 10, pp. 12–20

Dawod, G., 2006, New strategies in the utilization of GPS technology for mapping and GIS activities in Egypt, Submitted to CERM.

El-Fiky, g., 2005, GPS-derived Velocity and Crustal Strain Field in the Suez-Sinai Area, Egypt, Bulletin of Earthquake Research Institute, University of Tokyo, V. 80, pp. 73-86.

Featherstone, W., and Dent, V., 2002, Transfer of vertical geodetic control using only one GPS receiver: a case study, The Australian Surveyor, V. 47, No. 1.

NRI, Nile Research Institute hydrographic survey Database Nile Research Institute, National Water Research Center, El-Qanater, Egypt, 2006.

Reilinger, R., McClusky, S., Vernant, P., Lawrence, S., Ergintav, S., Cakmak, R., Ozener, H., Kadirov, F., Guliev, I., Stepanyan, R., Nadariya, M., Hahubia, G., Mahmoud, S., Sakr, K., ArRajehi, A., Paradissis, D., Al-Aydrus, A., Prilepin, M., Guseva, T., Evren, E., Dmitrotsa, A., Filikov, S., Gomez, F., Al-Ghazzi, R., and Karam, G., 2006, GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions, Journal of Geophysical Research, V. 111.

Soler, T. , Michalak, P. , Weston, N., Snay, R., Foote, R., and Michalak, P., 2006, Accuracy of OPUS solutions for 1-to 4-h observing sessions, GPS Solutions, No. 12, pp. 45-55

Witchayangkoon B., 2000, Elements of GPS precise point positioning, PhD Dissertation, University of Maine, USA.

Table 1: An overall assessment of online GPS processing services

Service name	Data transfer Method	Available options	Elapsed time to receive results (min)	Limitations of GPS data
AUSPOS	Uploading FTP	Antenna height Antenna type	>25	Min of 1 h Dual frequency static Max 7 RINEX files
PPP	Uploading	Mode of processing 2 Reference system	<3	No minimum Static or kinematic Max 6-day long Less than100 MB
SCOUT	FTP	Antenna height Antenna type Selection of reference stations	>15	Minimum of 1 h Dual frequency static
OPUS	Uploading	Antenna height Antenna type	>4	Minimum of 2 h Dual frequency static Max 24 h Static Only available for use in Central and North America
Auto-GIPSY	Sending the Anonymous FTP	None	<3	At least an hour

Table 2: Statistics of standard deviations of PPP service' results
(values are in meters)

	Obs. Time (hours)	$\sigma\ \phi$	$\sigma\ \lambda$	σ h	σ 2D	σ 3D
Minimum	2.7	0.005	0.017	0.027	0.018	0.032
Maximum	6.2	0.030	0.063	0.129	0.064	0.141
Mean	3.8	0.015	0.040	0.078	0.043	0.090

Table 3: Statistics of accuracy estimates of PPP service' results
(values are in meters)

	d_X	d_Y	d_Z	d_{2D}	d_{3D}
Minimum	-0.265	-0.130	0.012	0.079	0.120
Maximum	-0.077	0.136	0.149	0.266	0.268
Mean	-0.173	0.018	0.070	0.190	0.209

Table 4: Statistics of standard deviations of AUSPOS service' results
(values are in meters)

	σ_X	σ_Y	σ_Z	σ 2D	σ 3D
Minimum	0.005	0.008	0.005	0.009	0.011
Maximum	0.020	0.031	0.016	0.037	0.040
Mean	0.016	0.017	0.011	0.024	0.026

Table 5: Statistics of accuracy estimates of AUSPOS service' results
(values are in meters)

	d_X	d_Y	d_Z	d_{2D}	d_{3D}
Minimum	-0.299	-0.082	-0.021	0.183	0.196
Maximum	-0.179	0.078	0.093	0.300	0.302
Mean	-0.224	0.022	0.055	0.230	0.240

Table 6: Statistics of coordinates differences of PPP and AUSPOS services
(values are in meters)

	d_X	d_Y	d_Z	d_{2D}	d_{3D}
Minimum	-0.130	-0.089	-0.076	0.044	0.049
Maximum	0.060	0.055	0.060	0.157	0.175
Mean	-0.052	0.003	-0.016	0.086	0.098

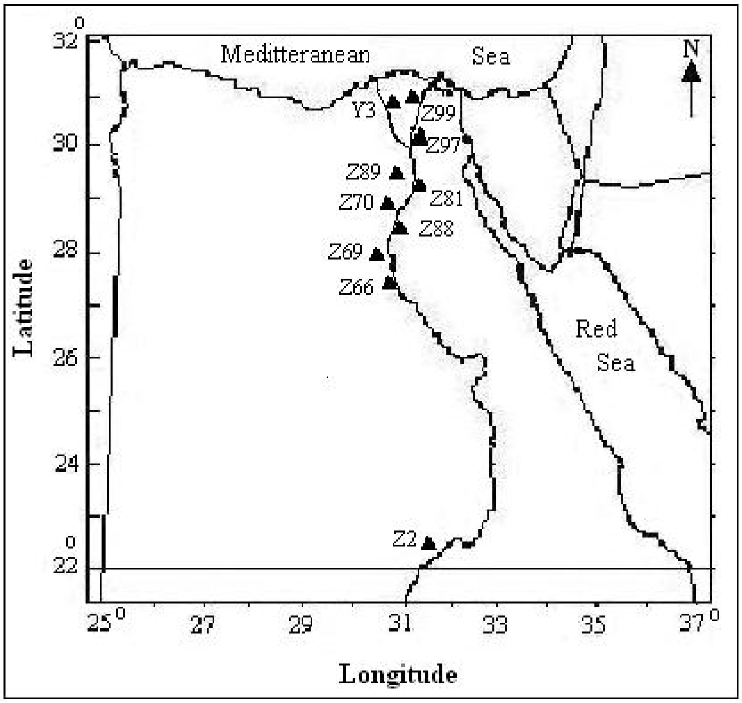

Figure 1: The utilized national GPS Stations

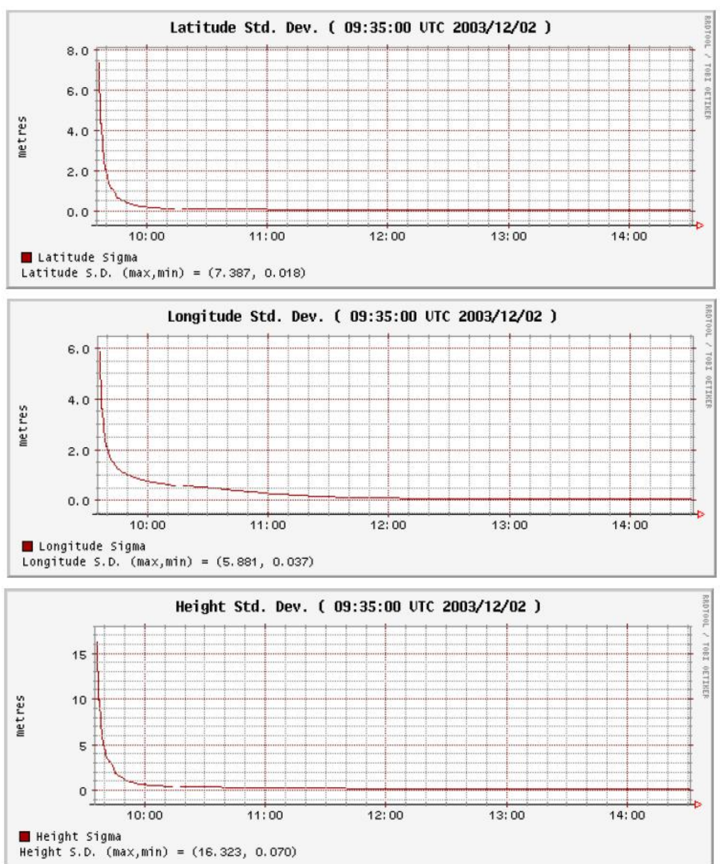

Figure 2: An example of Processing Standard Deviations of PPP results

Appendix 1

GPS Processing parameters used by the AUSPOS service

Observables	Ionosphere corrected L1 double difference carrier phase, Pseudo-range only used for receiver clock estimation, Elevation cut-off 15°, Sampling rate 30 seconds, Weighting 1.0 cm for double difference, elevation dependent 1 / sin (E).
Troposphere	Hopfield, Niell mapping function
Preprocessing	Receiver clocks estimated using pseudo-range information
Satellite center of mass correction	Block II x,y,z: 0.2794, 0.0000, 1.0259 m
	Block IIA x,y,z: 0.2794, 0.0000, 1.2053 m
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.
Atmospheric Drag	Jachhia Model
Earth's Gravitational (Static) Potential Model	EGM96 -degree and order 12
Solid Earth Tides (Dynamic) Potential	Love Model
Ocean Tide (Dynamic) Potential	Christodoulidis
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.
Geodesic Nutation	As in IERS TN 21, P. 37
Polar Motion	IGS Earth Orientation Parameters (Ultra-rapid, Rapid, Final) - apriori
Earth Rotation (UT1)	IGS Earth Orientation Parameters (Ultra-rapid, Rapid, Final) - apriori
Plate Motion	IGS Cumulative SSC
Reference Frame	IGS Cumulative SSC