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BENEFIT OF TIDAL OBSERVATIONS TO GRAVITY AND GPS NETWORKS

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أهمية قياسات المد و الجزر التثاقلى على دقة قياسات شبكات التثاقلية الأرضية و نظام تحديد المواقع العالمي GPS

الخلاصة: تعتبر ظاهرة المد والجزر التثاقلى من الظواهر التي تؤثر على غالبية القياسات الجيوديسية و قد يصل التغير في التثاقلية الأرضية نتيجة هذه الظاهرة إلى ٠,٣ مليجال و قد تصل الإزاحة الرأسية إلى ٤٠ سم و حوالي ثلث هذه القيمة للإزاحات الأفقية. و لذلك فإن التصحيح الدقيق من تأثير المد والجزر التثاقلى يعد أمرا مطلوبا ليس فقط لتصحيح القياسات المطلقة للجاذبية الأرضية و لكن أيضا للقياسات النسبية. إن التنبؤ بالمد و الجزر التثاقلى باستخدام التحديد المباشر لوضع القمر و الشمس لن يصل إلى الدقة الكافية حيث أن هذه الطريقة لا تأخذ في الاعتبار المعاملات المختلفة لموجات المد و الجزر التثاقلى و التي قد تصل إلي ١٠% من رد الفعل الطبيعي للأرض. و لأخذ هذه المؤثرات في الاعتبار نظريا فإنه يلزم استخدام قوائم المد و الجزر بالإضافة إلى نموذج أرضى، و لكن إذا أريد الوصول إلى دقة عالية فإنه يجب الاستعانة بمعاملات المد و الجزر المستنبطة من القياسات المستمرة للتثاقلية الأرضية حيث أنها تمثل رد الفعل الحقيقي للقشرة الأرضية لقوى المد في منطقة الدراسة.

و من ناحية أخرى فإن الدقة الحالية للقياسات الجيوديسية الفضائية جعلت هذه القياسات تتأثر بشكل كبير بالمد و الجزر و لذلك يجب الأخذ في الاعتبار الإزاحات المحلية الناتجة عن هذه الظاهرة. و لتصحيح هذه الإزاحات فإنه ينبغي الاستعانة بالإضافة إلى الحسابات النظرية رد الفعل الحقيقي للقشرة الأرضية المستنتج من قياسات المد و الجزر.

و قد تم أخذ شبكة أسوان الجيوديسية الإقليمية كتطبيق واقعي لهذه الدراسة. واستخدمت قياسات المد و الجزر لتقييم أهمية هذه القياسات على دقة قياسات شبكات التثاقلية الأرضية و بمنطقة الدراسة. و أوضحت هذه الدراسة أنه حتى باستخدام أدق الطرق النظرية فإنها لا ترقى في دقتها إلى تلك الناتجة عن أرصاد حقيقية للمد و الجزر التثاقلي.

ABSTRACT: *Earth tides affect almost all geodetic observations. Gravity tides can reach a magnitude up to 0.3mgal in equatorial regions and the displacements due to Earth tides can reach up to 40cm for the vertical component and about third of this value for the horizontal components. An accurate correction of tidal effects is thus required, not only for absolute gravity measurements, but also for the reduction of relative instruments. Global tidal prediction based on the position of Moon and Sun will never reach a sufficient precision, as they cannot take into account the systematic differences between the tidal factors of the different tidal waves. These differences can reach up to 10% with respect to the normal response of the Earth to the tidal forces. To take these effects into account theoretically, it is necessary to use a tidal potential development. The precision of the tidal prediction will of course depends from the number of terms in the potential, from 505 in Cartwright-Tayler-Edden (CTE505) development to 12,935 in Hartmann-Wenzel one. To achieve a higher accuracy, observed tidal factors obtained with a well-calibrated gravimeter have to be applied to represent the real response of the crust in the studied region.*

On the other hand, the present quality of modeling of space techniques such as GPS is in principle sensitive to the tidal effect. Accurate determination of the local site displacements due to Earth tides has to be taken into account. An improved tidal correction demands, in addition to the theoretical calculations of the tidal displacements, the real response to the tidal wave deduced from the tidal observations.

Aswan regional geodetic network has been used as a case study for the current work. The obtained tidal parameters, due to the tidal observation representing the real response of the Earth have been used to study the benefit of tidal observations on the accuracy of gravity and GPS geodetic networks. The study shows that, even when using an accurate theoretical prediction of the gravity and displacements tide, observed tidal parameters are needed if a higher accuracy is to be achieved.

INTRODUCTION

The gravitational attraction of the Moon and Sun, as they and the Earth move with respect to each other, imposes periodic forces on the solid Earth, oceans and atmosphere. The response of each of these parts of the Earth to the tidal force affects almost all precise measurements of the Earth. For this reason, tides are important both for the correction of precise measurements and as an input signal for the evaluation of the structure and properties of the Earth.

The tidal acceleration $b^{\rightarrow}$ in an observation point P on the Earth's surface results from the sum of the gravitational acceleration $a_p^{\rightarrow}$ generated by a celestial body at point P and of the orbital acceleration $-a_0^{\rightarrow}$ due to the motion of the Earth, as shown in figure 1.

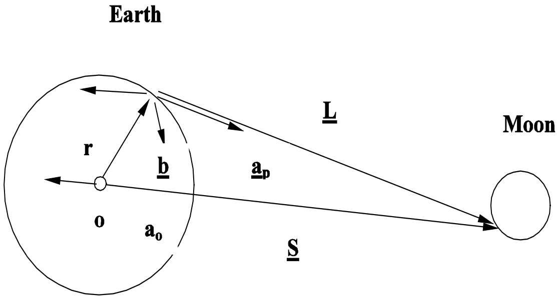

Fig.1: Tidal acceleration

Applying Newton's gravitational law, the tidal acceleration vector $\vec{b}$ is given by:

$$\vec{b} = \vec{a}_p - \vec{a}_0 = \frac{GM_b}{d^2} \cdot \frac{\vec{d}}{d} - \frac{GM_b}{s^2} \cdot \frac{\vec{s}}{s} \qquad (1)$$

The tidal acceleration vector $\vec{b}$ is, by definition, the gradient of the tidal potential V:

$$\vec{b} = \overrightarrow{grad} V = \frac{\partial V}{\partial \vec{r}} \qquad (2)$$

At the geocenter, where $\vec{r}=0$, the tidal potential vanishes and eq. (2) can be written as:

$$V = \frac{GM_b}{s} \cdot \left(\frac{1}{d} - \frac{1}{s} - \frac{r.\cos\Psi}{s^2}\right) \qquad (3)$$

with ψ = geocentric zenith angle and eq. (3) can be expanded into Legendre polynomials $P_1(\cos\psi)$ (eg. Wenzel, 1997) as:

$$V = \frac{GM_b}{s} \cdot \sum_{l=2}^{\infty} \left(\frac{r}{s}\right)^l P_l(\cos\Psi) \qquad (4)$$

ψ can be expressed by geocentric spherical coordinates of the station and of the celestial body as:

$\cos\psi = \cos\Theta \,.\, \cos\Theta_b + \sin\Theta \,.\, \mathrm{Sin}\,\Theta_b \,.\, \cos(\lambda - \Lambda_b)$ (5)

where ψ is the geocentric zenith angle of the celestial body, Θ is the geocentric spherical polar distance of the station, λ is the geocentric spherical longitude of the station, Θ_b is the geocentric spherical polar distance to the celestial body and Λ is the geocentric spherical longitude of the celestial body. Eqs. 4&5 indicate that, the tidal potential is position and time dependent.

The tidal potential V causes a radial shift Δ_r of the attracted point P. The corresponding mass displacement causes a deformation of potential V_d. Radial deformation Δ_r and the deformation of potential V_d are proportional to the tidal potential V. The tidal potential of the elastic Earth V_d and V_{el} can be described by the theory of Love (1909) (eg. Torge, 1989) as:

$$V_{el} = V_t + V_d - g\Delta_r = V_t(1 + k - h) \qquad (6)$$

where: Love's parameters k = k (r) and h = h (r) appear as proportion factors. k and h depend on the degree of the spherical harmonic expansion of the tidal deformation.

THEORETICAL COMPUTATIONS OF THE TIDAL POTENTIAL

Earth tide force is considered to be the only global phenomena, which can be predicted accurately. The accuracy of predicting the tidal potential depends on the accuracy of the determination of the radius of the Earth, distance to the celestial body and its coordinates, which nowadays can be determined with a very high accuracy.

Generally, computation of the functional of the tidal potential at a specific station and epoch can be carried out using one of the following methods:

1- Computation of the tidal potential using the ephemeredes of the celestial bodies (Moon, Sun and planets). The practical application of this method is restricted to less precise requirements, because it is impossible to estimate precisely the elastic Earth covered with ocean using the ephemeris method.

2- Expansion of the tidal potential either by analytical spectral analysis or by numerical spectral analysis of the tidal potential generated by the celestial body to produce a tidal potential catalogue (amplitudes, phases and frequencies for tidal waves). Accuracy and number of waves of the available tidal potential catalogue is given in table 1.

Table 1: Available tidal potential catalogues

Author	No. of waves	Accuracy nm/s^2
Doodson (1921)	377	1.0408
Cartwright (1971)	505	0.3488
Buellesfeld (1985)	656	0.2402
Xi (1989)	3070	0.0642
Tamura (1993)	2060	0.0308
Roosbeek (1996)	6499	0.0200
Har.Wen. (1995)	12935	0.0014

EARTH TIDE OBSERVATION

Earth tide observations have been carried out at many stations on the globe. The original aim of such observations is to determine the global response of the Earth to the tidal forcing. Thus, tidal observations are important both for accurate determination of the tidal correction of precise measurements and to evaluate the structure and elastic properties of the Earth. Higher accuracy is needed for the instruments, correction for the local perturbation and data analysis before the body tide signal can be gleaned from the observations and information about the elastic three-dimensional properties of the Earth can be retrieved.

Earth tides can be observed by gravimeters, tilt- and strainmeters. However, gravity tides can be measured with very high signal to noise ratio with superconducting and Lacoste- Romberg with electrostatic feedback gravimeters (Zuern, 1997). In contrast to gravity tide, which is very weakly distorted by local, regional and large scale deviations of the Earth from spherical symmetry, tidal field measured by tilt- and strainmeters are heavily distorted by local heterogeneities to the extent, that global and regional responses of the Earth cannot be measured reliably with such Instruments. Thus, gravity tides are considered to be the most common method to obtain the response of the Earth to the tidal force.

Figure 2 shows the objective of the Earth tide observations, where the reaction of the earth to the tide in the frequency domain is:

$$\underline{Y}_{(f)} = H_{(f)}.X_{(f)} \qquad (7)$$

$X_{(f)}$ = tidal spectrum.

$Y_{(f)}$ = observed tidal spectrum.

$H_{(f)}$ = transfer function.

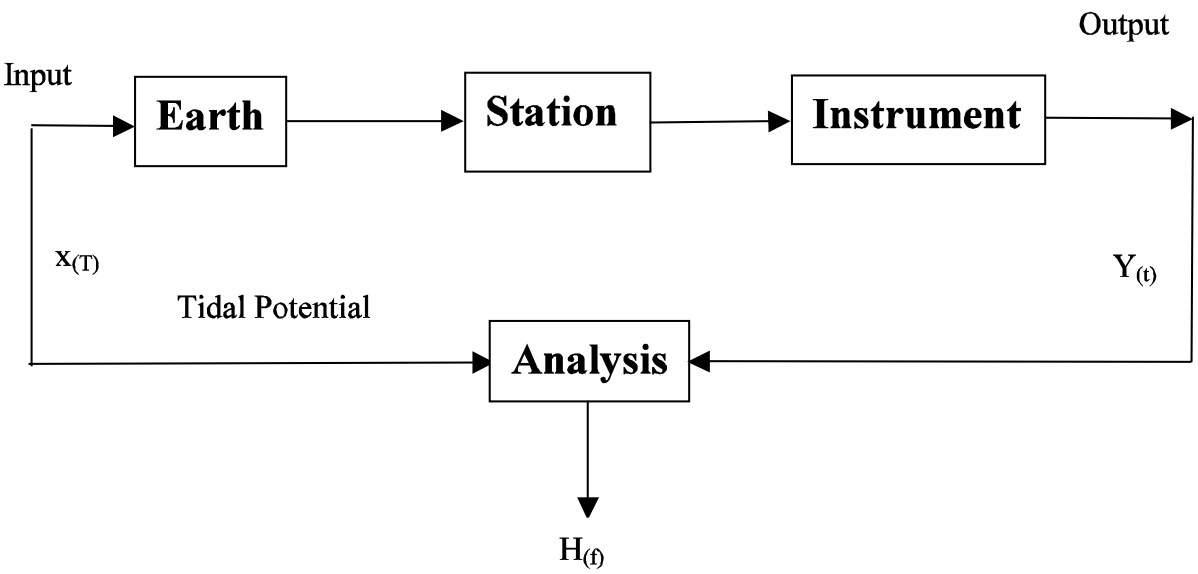

Fig 2: Objective of the analysis of Earth tide observations, after Wenzel (1997).

The tidal response of the Earth is usually expressed as the gravimetric factor and phase shift for specific tidal frequencies or in the form of Love numbers. This can be done by comparing the observed gravimetric Earth tides to a model of the rigid Earth as:

$$\delta_i = A_i(observed) \ : \ A_i(theor) \qquad (8)$$

where: δ_i is the gravimetric factor at the amplitude A_i

$$\Delta\Phi_i = \Phi_i(observed) \ - \ \Phi_i(theor) \qquad (9)$$

where: Φ_i is the phase shift.

The Love parameters h and k depend on the spherical harmonic of δ as:

$$\delta_l = 1 + \frac{2}{l}h_1 - \frac{l+1}{l}k_l \qquad (10)$$

For spherical harmonic expansion through l=2, then:

$$\delta_2 = 1 + h_2 - \frac{3}{2}k_2 \qquad (11)$$

Using the global average of h and k (h_2=0.61 and k_2=0.30), δ=1.16

TIDAL CORRECTION

Gravimetric tidal correction can be determined in the following methods:

- Computation from the expansion of the tidal potential for the rigid Earth with a global gravimetric factor δ = 1.16 and phase shift of zero. This method is mainly used in the gravity softwares.
- Computation of the tidal potential using tidal potential catalogue and elastic tidal parameters from

an elastic Earth model and a model of ocean tide. This method is usually used in precise gravity networks, where tidal observations do not exist.

- Using the tidal parameters deduced from measurements of the gravimetric Earth tides, which represent the real response of the Earth to the tidal force. This method is used for an accurate gravity networks adjustment, where there are tidal gravity observations at the studied region.

On the other hand, correction of the site displacements due to Earth tides can be calculated using the Love number (eq. 6). Equation 9 indicates that, second order harmonic expansion of the Love numbers is dominant, but higher degree expansion, expressing the long period tide, is needed if a higher accuracy to be achieved. calculated using the Love number (eq. 6). Equation 9 indicates that, second order harmonic expansion of the Love numbers is dominant, but higher degree expansion, expressing the long period tide, is needed if a higher accuracy to be achieved.

The response R of the Earth to the tidal force can be written as: R = h*F, where: F is the tidal force and h is known as the Love number, which characterizes the transfer function (how the deformable Earth reacts to a unit forcing). F has several components: periodic components as semi-diurnal, diurnal, long period (e.g. monthly and annual), and a secular component. The Earth responds differently to all of these components. As a consequence, the Love numbers h also depend on the time-scale of the component of the force F, where we should write:

$$R = h_d * F_d + h_s d * F_s d + h_l * F_l + h_s ec * F_s ec \qquad (12)$$

The work of Love on tides showed that, the response of the (spherical) Earth is dependent on the degree n of the tidal deformation and that:

- Global Love number deduced from an Earth model, higher degree Love numbers will be ignored.

- Determination of the real Love numbers using either tidal observation or seismological data.

CASE STUDY: ASWAN REGIONAL GEODETIC NETWORK

The area of the northern part of Nasser's Lake is one of the most strategic regions in Egypt, where the high dam exist. Many geodetic and geophysical activities have been initiated in this region after the occurrence of November 1984 and the continued seismological activities. The aim of these activities is to understand the seismic mechanism in this region, recent crustal movements studies around the active faults responsible for the seismological activities and the possible relation between variation of the water level of the lake and the seismic activities.

One of these activities is the establishment of Aswan regional geodetic network. The network comprises of 11 stations and bounds the northern part of Nasser's lake. Distribution of the network stations of around the northern part of the lake is given in figure 3.

The main object of this research is to determine the change in the gravity field and crustal deformation, as deduced from GPS observations, and the implementation of these variations in vicinity of variable level of the lake, crustal deformations and the seismological activities. For this task, gravity and GPS observations have been repeated at different epochs along the points of the network. Figure 4 shows the gravity variation along the network at the period from November 2001 to November 2003.

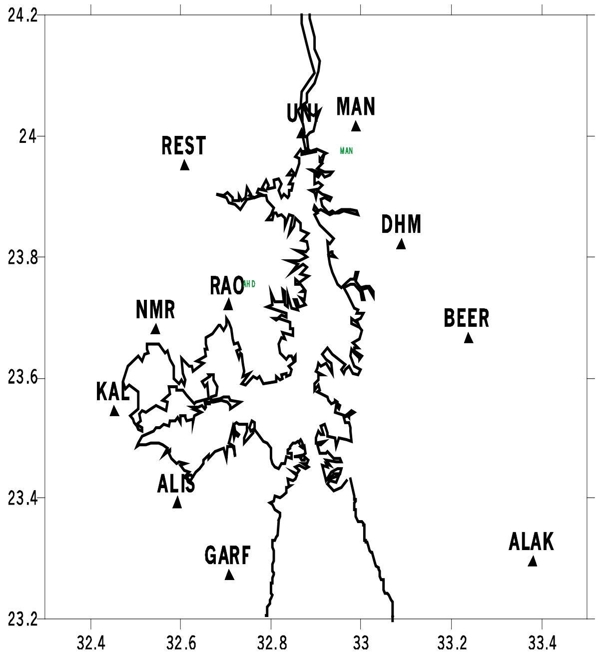

Fig. 3: Aswan regional geodetic network.

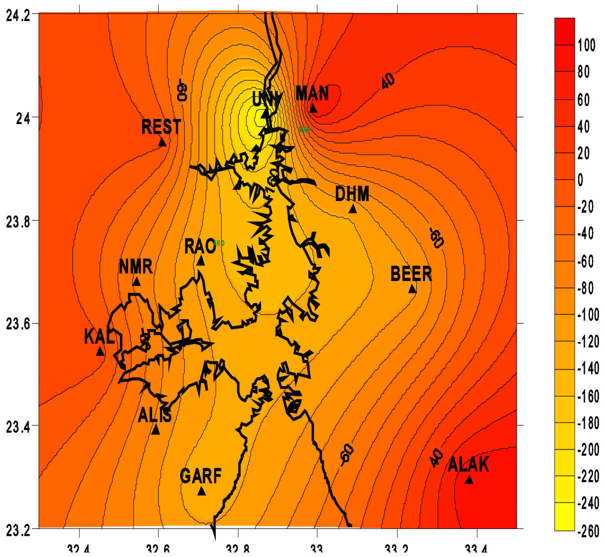

Fig. 4: Gravity variation along Aswan regional geodetic network at theperiod

The figure indicates that the annual gravity variation around the lake is in the order of tens of microgals. On the other hand, the crustal deformation around the lake is in the order of few millimeters. Thus, studying such fine phenomena with higher accuracy in both gravity and GPS is needed and inconsequence accurate determination of gravity variation and local site deformation due to Earth tides are needed.

ASWAN GRAVIMETRIC TIDAL STATION

Because of the mentioned importance of the northern part of Lake Nasser, a gravimetric tidal station has been established within it. Thus, the Lacoste & Romberg gravimeter D-218 of the National Research Institute of Astronomy and Geophysics, Helwan (NRIAG) has been installed at a well-isolated chamber at the seller of the Telemetric Seismological station at Sahari, Aswan, which is very close to the Lake Nasser.

The main objective of this research is to carry out continuous gravity observations in the Nasser Lake region to determine the variation of the elastic behavior as a result of the variable load of the lake. Another purpose of this study is to determine the effect of the load variation of the Lake to the geodetic observations. A final objective of this study is to determine the elastic parameters representing the real response of the crust to the tidal forcing on this region.

The response of the crust to the tidal force is given, as indicated from equations 8 and 9, in the form of amplitude factor and phase shift at certain amplitude of the tidal wave. Table 2 shows the elastic parameters of some tidal waves of different amplitudes and table 3 shows the Love and Shida numbers, as computed from the harmonic analysis of the tidal observation at Aswan tidal station.

Table 2: Tidal parameters from the tidal observation at Aswan Earth tide station

wave	Amplitude [nm/s**2]	Amplitude factor δ	Phase lead $\Delta\Phi$
M_f	56.745	1.15000	0.0000
O_1	350.930	1.14882	0.0804
K_1	488.168	1.13599	0.2062
N_2	69.101	1.17054	2.5425
M_2	365.141	1.18705	2.0327
M_3	4.124	1.06234	0.3783

Table 3: Love and Shida numbers for Lake Nasser region

deg.	ord.	h	k	i
2	0	0.613776	0.308498	0.082679
2	1	0.606109	0.299317	0.086361
2	2	0.613367	0.303520	0.085067
3	0	0.294600	0.094200	0.014900
3	1	0.294600	0.094200	0.014900
3	2	0.294600	0.094200	0.014900
3	3	0.294720	0.094481	0.014900

COMPARISON OF DIFFERENT TIDAL CORRECTION METHODS TO THE REPEATED GRAVITY OBSERVATIONS AT ASWAN REGIONAL GEODETIC NETWORK

In this section, gravimetric tides will be predicted using the three tidal prediction methods, mentioned in section 4, at the Aswan regional geodetic network. Two points of the network, Alisa and Alaqi, will be used as a representative for the network.

Accurate theoretical prediction of the gravimetric tides required the development of a tidal potential or a tidal potential catalogue, as explained in section 2. At each of the selected points of the network gravimetric tides has been predicted using the available six tidal potential catalogues, as given in table 1. Figures 5&6 show that, gravity tide variations during 2003 at Alisa and Alaqi points of the network, using the six different tide potential catalogues.

The figure shows that the maximum difference of the available catalogues is 3 microgals and the difference between the recent 3 catalogues is less than 2 microgals. As these two values are below the instrumental error, each of the valid tidal potential catalogues can meet the requirements of accurate gravity observations at the network. However, in an accuracy assessment study of the valid tidal potential catalogues, Wenzel (1996) showed that the HW95 tidal potential catalogue has a higher accuracy in both time and frequency domain and fulfills the accuracy requirements for the analysis of precise geodetic observations. Thus, this catalogue will be used in the computations of the current study.

Gravimetric tide has been predicted using each of the mentioned prediction methods, as given in section 3, at the selected stations of the regional network and are given in figures 7 and 8.

Figures 7 and 8 show the predominant tidal period in the semidiurnal band, as the amplitude of the semidiurnal waves varies from the maximum at the equator to zero at the pole. The figures also show remarkable differences between using each of the tidal prediction methods in both amplitude and phase. The standard deviation of the amplitude between the three tidal prediction methods is in the order of 45 nm/s^2 and about 6 hours phase delay. A much less standard deviation of both amplitudes, 20 nm/s^2 and phase, 2 hours, after ignoring using a fixed tidal parameter. Using observed tidal parameters enables accurate and complete tidal prediction, because these parameters represent the real response of the Earth to the tidal force in the studied region. Thus, observed tidal parameters can be considered to be much close to reality and deviation from it can be considered as a misrepresentation in the tidal prediction. Therefore, difference in gravity tide predictions between using observed tidal parameters and fixed and theoretical tidal parameters are computed at the selected points and given in figures 9 and 10.

The figures indicate a semidiurnal residual when using fixed tidal parameters at 80 nm/s^2. This indicates that, using a fixed tidal parameter did not predict the gravimetric tide completely. On the other hand, better residual obtained when using an accurate theoretical tidal parameters of 30 nm/s^2. Although the achieved accuracy, using accurate theoretical parameters, seems to be sufficient for the analysis of precise gravity network, but daily prediction of the tides did not consider the long periodic tidal component. Moreover, practically gravity variations are determined by comparing the gravity observations at different epochs and hence long period tide plays an important role. For this reason, gravity tide has been predicted using the previous methods at the selected points, but through a complete year. Figures 11 to 14 give the difference in gravity tide predictions between using observed tidal parameters and both fixed and theoretical tidal parameters during 2003

Figures (11-14) show that, using a fixed tidal parameter, the residual can reach 150 nm/s^2, while using accurate theoretical parameters, the residual can improve to 60 nm/s^2. The figures indicate also that, the residual has a periodic behavior typical to the tidal period, even when using accurate theoretical parameters.

Based on these results, it can be concluded that, using fixed tidal parameters can produce errors relative to the required accuracy needed on the adjustment of geodetic networks for the geodynamic purposes. Although using accurate theoretical parameters, a remarkable improvement can be obtained, but their still residuals affect the accuracy of the gravity network adjustment. Finally, using observed tidal parameters is important for an accurate adjustment of the gravity network for geodynamic subjects, where higher accuracy is needed.

COMPARISON BETWEEN DIFFERENT TIDAL CORRECTION METHODS TO SITE DISPLACEMENTS AT ASWAN REGIONAL GEODETIC NETWORK

Section 4 indicates that, Earth tides site displacements can be predicted either by using Love numbers based on Global Earth models or those deduced from tidal or seismological observations. In this section, comparison is introduced between different vertical displacement prediction methods to the selected stations of the Aswan geodetic network. Using theoretical Love numbers does prediction and those computed from the harmonic analysis of the tidal observations at Aswan tidal station that is given in table 3. It is useful to evaluate the magnitude of vertical displacement due to Earth tides at the selected stations. Thus, vertical displacement has been computed using the observed tidal parameters at both stations during 2003 that are presented in figures 15 and 16.

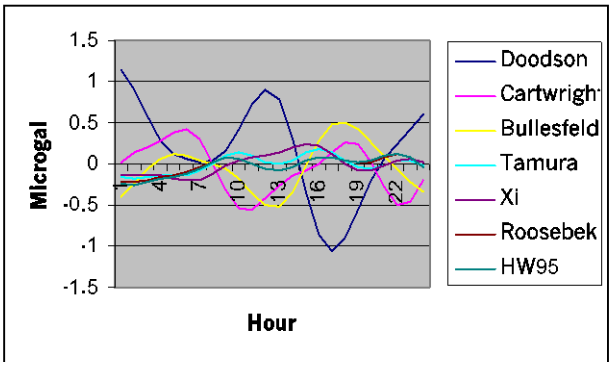

Fig. 5: Gravity tide variation at station Alisa at 1.1.2003 using 6 different tide potential catalogues.

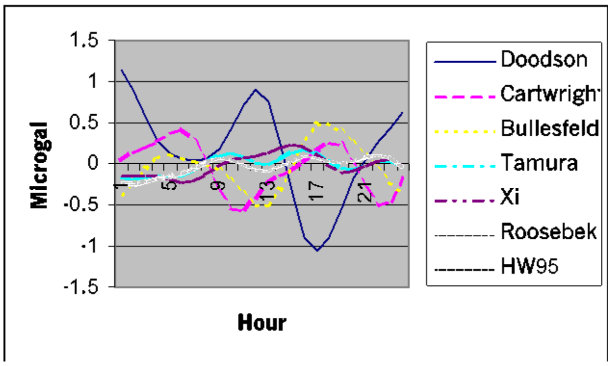

Fig.6: Gravity tide variation at station Alaqi at 1.1.2003 using 6 different tide potential catalogues.

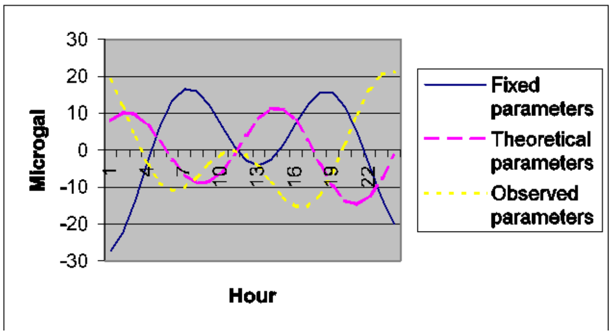

Fig. 7: Gravity tide variation at station Alisa at 1.1.2003 using 3 different gravimetric tide prediction methods.

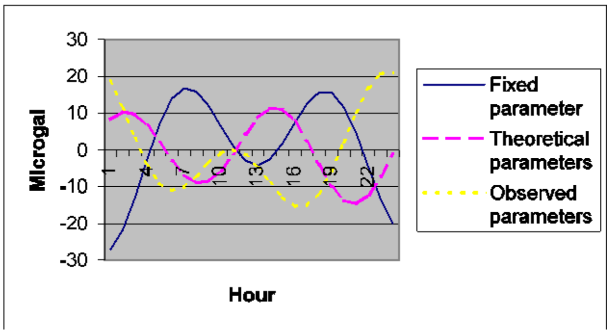

Fig. 8: Gravity tide variation at station Alaqi at 1.1.2003 using 3 different gravimetric tide prediction methods.

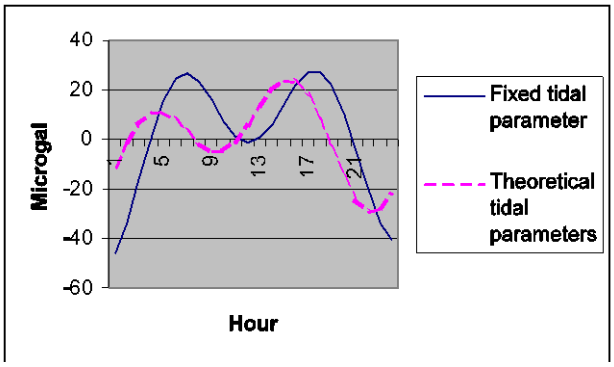

Fig. 9: Gravity tide error at station Alisa at 1.1.2003 using fixed tide parameter and theoretical tide parameters.

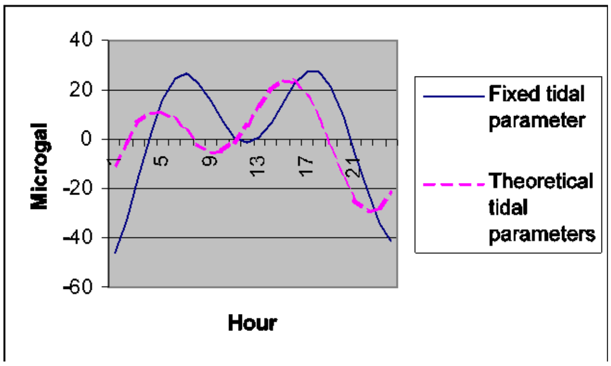

Fig. 10: Gravity tide error at station Alaqi at 1.1.2003 using fixed tide parameter and theoretical tide parameters.

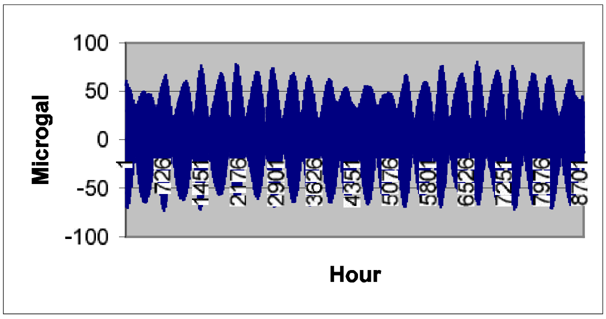

Fig. 11: Gravity tide error at station Alisa during 2003 using fixed tide parameter.

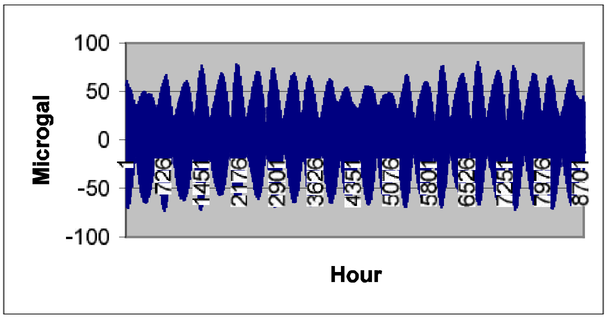

Fig. 12: Gravity tide error at station Alaqi during 2003 using fixed tide parameter.

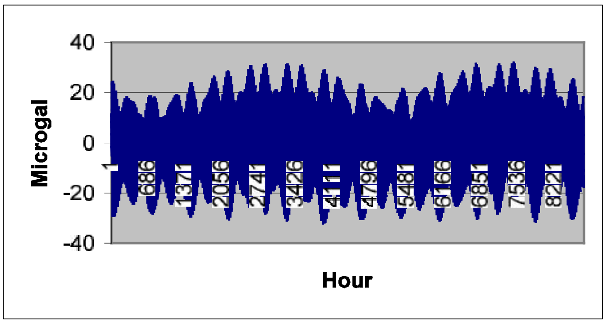

Fig. 13: Gravity tide error at station Alisa during 2003 using theoretical tide parameters.

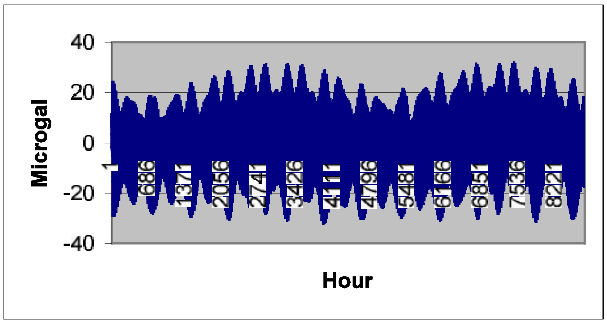

Fig. 14: Gravity tide error at station Alaq during 2003 using theoretical tide parameters.

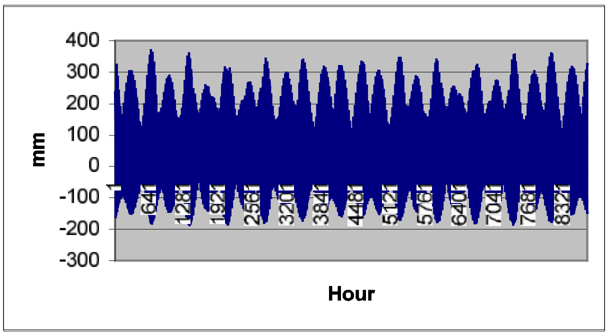

Fig. 15: Vertical displacement due to Earth tides at station Alisa during 2003.

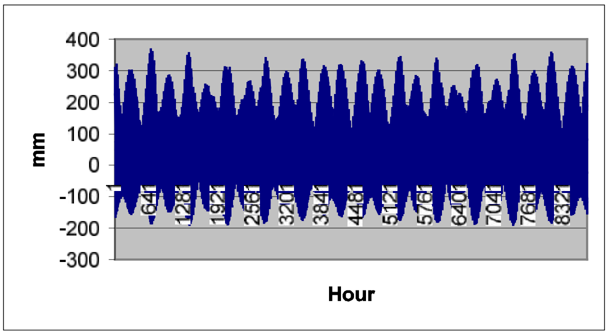

Fig. 16: Vertical displacement due to Earth tides at station Alaqi during 2003.

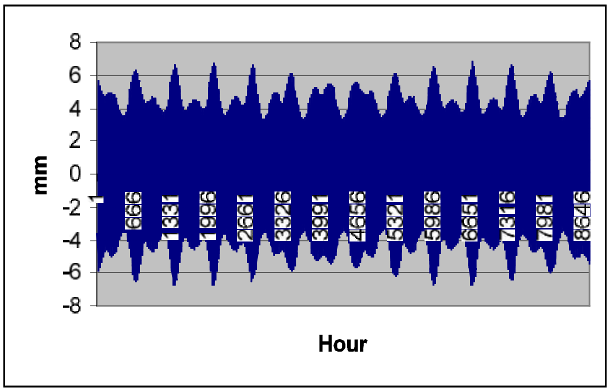

Fig. 17: Difference in Earth tides vertical displacement predicted using theoretical and observed Love numbers at station Alisa during 2003.

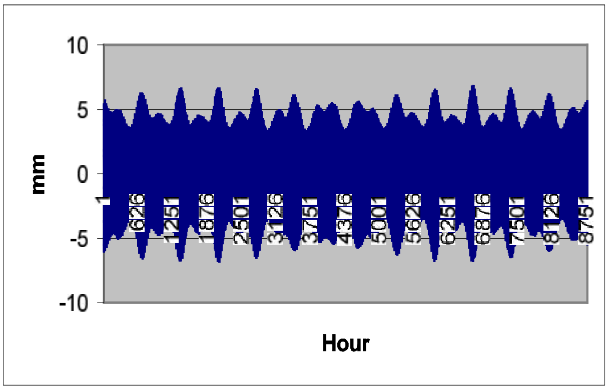

Fig. 18: Difference in Earth tides vertical displacement predicted using theoretical and observed Love numbers at station Alaqi during 2003.

Figures 15 and 16 show that, Earth tides produce high vertical displacement in the order of 50 cm on both stations. The strong tidal deformation in this region indicates the requirement of an accurate correction of this phenomenon if higher accuracy is needed.

At each of the selected stations, vertical displacement due to Earth tides has been predicted using the theoretical and observed Love numbers. Figures 17 and 18 show the difference in Earth tides vertical displacement predicted using the theoretical and observed Love numbers at both stations during 2003.

Figures 17 and 18 indicate a remarkable difference between the two prediction methods and the difference can reach 16 mm. However, these differences should decrease when the GPS coordinates are computed on a daily basis due to the averaging on one day. On the other hand, absolute GPS coordinates from a single station are usually of low accuracy and the results are of low interest to geodetic application (Seeber, 1993). For this reason, a multistation adjustment technique is employed, in which the data of a number of receivers operating simultaneously, are processed in a joint adjustment. These receivers form a network and a number of baselines between stations. Results are usually the coordinates differences between two receivers connected by a certain baseline. During the analysis of the measurements, by applying the double difference of the observations only, the difference in the tidal deformation between both points will be considered. In local networks, the deformation is only slightly different and will be cancelled by forming differences. But one of the advantages of applying space techniques for geodetic purpose, such as GPS, is the possibility of monitoring geodetic networks on a regional or even global scale. Zahran (2000) shows that, the difference in the tidal deformation when applying the double difference technique increases as the baseline length increases.

Therefore, the remaining effect of Earth tides displacements prediction methods when applying the double difference techniques along the baseline connecting the two selected stations at Aswan regional network are computed. Differences in Earth tides vertical displacement predicted using theoretical and observed Love numbers at Alisa-Alaqi baseline during the time domain is given in figure 19.

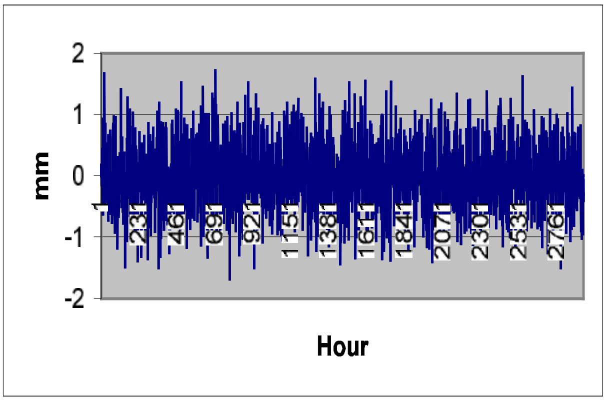

Fig. 19: Difference in Earth tides vertical displacement predicted using theoretical and observed Love numbers at Alisa-Alaqi baseline during 2003.

The figure shows that the remaining residual along the baseline is about 3 mm. Although there is a remarkable improvement when applying the difference across a baseline, but the residual is still in the order of the studied geodynamical phenomenon of the region of lake Nasser.

CONCLUSIONS

Based on results of the current study following conclusions can be drawn:

- Accurate application of tidal correction is very important in both gravity and GPS observations.
- Direct Solar and Lunar tides using Longman formula is not the appropriate tidal correction for the geodynamical studies.
- Accurate tidal correction to gravity network requires a modern tidal potential catalogue.
- Observed tidal parameter is needed, if a higher accuracy of the gravity network to be achieved.
- About 20% improvement of the mean error of Aswan gravity network is needed after using the observed tidal parameters.
- Accurate tidal correction to GPS network requires an accurate Love and Shida number up to the third order.
- Observed tidal parameters is also needed at the GPS network if the millimeters accuracy of the vertical component to be achieved.

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