Investigating the Effect of Using the Local Datum Instead of WGS-84 in Processing the GPS Observations

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يستخدم نظام ال GPS في الآونة الأخيرة في كثير من الأعمال المساحية والمدنية حيث يعمل ال GPS بسرعة ودقة عاليتين مقارنة بالطرق المساحية التقليدية. لذلك يقدم هدا البحث دراسة دقة طريقة مختلفة لاستنتاج أو إيجاد الأحداثيات المحلية لنقاط مأخوذة أرصادها باستخدام GPS تتلخص الطريقة التقليدية للحصول على الأحداثيات المحلية بعمل معالجة لأرصاد GPS مع أحداثيات نقطة ال Base station فيWGS84 ثم تطبيق عناصر التحويل على الإحداثيات الناتجة فيمكننا الحصول على الإحداثيات المحلية المناظرة. أما الطريقة الجديدة تتم بمعالجة أرصاد ال GPS مع استخدام الأحداثيات المحلية لنقطة ال Base station ليتم الحصول على الإحداثيات المحلية لباقي النقاط مباشرة. تمت مقارنة النتائج باستخدام الطريقتين من خلال أرصاد حقلية مأخوذة في أماكن مختلفة في مصر. وأيضا عرض نتائج المقارنة في صورة جداول وأشكال بيانية لمعرفة الى أى مدى يتم استخدام هده الطريقة

Abstract

In Egypt, like in many countries, there is uncertainty problem in transfo:-ming the results of GPS into local coordinates. Escaping from that, some GPS users utilize the local coordinates of the base station directly to produce the local coordinates of the rover stations. In this research, this concept is applied using real observations at different locations in Egypt. The observations are processed rigorously and the WGS84 coordinates are rigorously transformed into local coordinates. GPS observations are processed once more using local coordinates at the base stations and the local coordinates of the rover stations are directly obtained. The outputs from the two cases are compared. The results are tabulated and graphically represented. A linear trend model is established to estimate the shift in latitude, longitude and height depending on the length and azimuth of the base line. The after all word is to which limit from the base station, this concept could be used taking the precision of the results into consideration.

1- Introduction

Traditionally, the surveying work was and still executed in the local system of coordinates depending on at least two known stations. The traditional instrument is occupying one known station and it is oriented at another known one. The computations are going forward in the local system. In the past two decades GPS is used extensively in the surveying works. This revealed some kind of problem for some users. The obtained results from GPS are WGS84 coordinates while, in most of the cases, the coordinates are required in the local datum. Details of GPS and its applications can be found in e.g. [Hofman-Wallenhof et al, 2002] and [Seeper, 2003]. Therefore

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transformation of coordinates process should be done. This process needs a set of transformation parameters. In many countries, Egypt is one of them, it is not easy to have such set of parameters because of the lack of accuracy and consistency in the primary geodetic network and the lack of GPS observations, [Awad, 1997]. To overcome this obstacle, some GPS users utilize the local coordinates of the base station in processing the GPS observations. They consider the output of the GPS observation processing as local coordinates. In this research, the resulted bias (shift) due to this process is investigated using actual GPS observations taken at different dates and different locations.

2- The Used Data

The used data in the computations are GPS observations collected at different locations in Egypt along different years. The used receivers are Leica dual frequency, capabilities of those receivers are given in [GPS system 300, 1996]. A reliable seven transformation parameters for Egypt, taken from [Saad, et al, 1998] are used. Thirty one common points were available, 15 points were used in the solution and 10 points were used to check the solution. Six points were rejected. The residuals of the solution at the data points ranged from 0.11 to 1.43 m with mean value 0.48 m and Stdv 0.37 m. The residuals at 10 check points ranged from 0.12 to 1.63 m with mean value 0.89 m and Stdv 0.64 m.

3- The Methodology

The following procedures are followed in every case;

- The GPS collected observations are processed using WGS-84 coordinates for the base station, the WGS-84 coordinates of the rover stations are obtained.
- The WGS-84 coordinates of the base and rover stations are transformed, using rigorous transformation parameters, to their corresponding local coordinates named Local Datum (LD)
- The ($\emptyset$, λ, H) in the Egyptian datum of the base station are used in processing the observations once more, the coordinates of the rover stations are directly obtained and named (LD-1).
- Differences between the results of the above two cases, in latitudes, longitudes, and heights ($\Delta\emptyset$, $\Delta\lambda$, ΔH) are computed. ΔH is the difference

between the orthometric height and the corresponding resulted height from the GPS.

- ΔØ and Δλ in arc seconds are expressed in meters by multiplying their values by 30 as an average value overall the area of Egypt.
- Horizontal resultant is computed as (sqrt($\Delta Ø^2+\Delta\lambda^2$)) and the relative difference is computed as (resultant / distance). The area of a circle is computed in every case with the baseline as radius of that circle to show if the obtained shift satisfies the required precision within that area or not.
- Graphs are illustrated to show the behavior of the differences against the lengths of the base lines.

4- Results and Analysis

The results are tabulated in four groups. Group 1 includes the results of the cases up to 3 kilometers base line length. Group 2 includes the results of the cases from 3 to 7 kilometers length. The third group includes the results of the cases from 7 to 15 kilometer baseline lengths. Group 4 includes one long base line. A linear trend in the form of :

$$\text{shift} = a_o + a_1 \text{ (length)} + a_2 \text{ (azimuth)}$$

is computed to relate the shift in latitude, longitude, and height with the length and azimuth of the base line. The linear trend is computed for the first three groups. In group 1, 9 cases are used in the solution and 4 cases are used as check cases. In group 2, 7 cases are used in the solution and 4 cases are used as check cases. In group 3, 4 cases are used in the solution and 1 case is used as check case. The three coefficients in every case are computed and the residuals of the trend model at the solution and check cases are computed.

4-1 Group 1: Baselines up to 3 Kilometers

Table (1): Data and results of group1 (up to 3 km base lines)

Point-point`	Dist. to base(m)	Azimuth (Deg)	ΔØ (cm)	Δλ (cm)	Result (cm)	ΔH (cm)	Result/Dist	Area (feddan
St1-St1`	181	222	0.0	0.0	0.0	-0.9	1:180000	25
St8- st8`	437	353	-1.1	0.2	1.1	0.4	1:40000	140
S11-S11`	643	163	0.8	-0.7	1.1	1.9	1:60000	300
S7-S7`	1019	233	1.1	1.0	1.6	-2.7	1:64000	760
m30-m30`	1061	12	-1.0	-1.3	1.64	3.4	1:65000	825
St5-St5`	1562	43	-1.9	-1.3	2.3	4.6	1:68000	1790
S5-S5`	1739	52	-2.1	-1.6	2.7	4.1	1:65000	2220
S13-S13`	1932	230	1.6	1.7	2.33	-3.9	1:82000	2740
f1-f1`	1981	22	-2.1	-1.8	2.76	4.1	1:72000	2880
S15-S15`	2767	229	3.2	1.9	3.8	-6.7	1:73000	5615
S3-S3`	2768	52	-3.4	-2.4	4.3	7.2	1:65000	5620
S4-S4`	2927	241	3.7	2.2	4.31	-7.5	1:68000	6285
115-115`	2966	17	-4.0	-2.6	4.77	7.7	1:63000	6455

From Table (1) it can be seen that the shift in the latitude, it has negative sign when the baseline goes to the north direction. It has positive sign when the baseline goes to the south direction. The absolute shift value ranges from 0.0 to 4.0 cm along base lines up to 3 km. Figure (1) illustrates the absolute values of the latitude.

Concerning the shift in the longitude, the shift has negative sign when the baseline goes to the east direction. It has positive sign when the baseline goes to the west direction. The absolute shift value ranges from 0.0 to 2.6 cm. Figure (2) illustrates the absolute values of the shift in longitude.

The horizontal resultant of the shift ranges from 0.0 to 4.77 cm. The horizontal resultant values are illustrated in Figure (3). Figures (4) illustrates the case of the horizontal shift for the first group, up to 3 km.

The relative horizontal shift in its worst value is 1:40000 and the best value is 1:82000 excluding the value 1:180000.

The absolute shift in height ranges from 0.4 to 7.7 cm. Figure (7) illustrates the absolute shift in heights.**The above mentioned trend model is computed using the data in Table (1) and the results were as follows:**

- **Latitude shift:** the residuals of the trend model at the solution cases range from –0.3 to 0.5 cm and at the check cases they range from –0.8 to 0.0 cm.
- **Longitude shift:** the residuals of the trend model at the solution cases range from –0.2 to 0.2 cm and at the check cases they range from 0.0 to 0.2 cm.
- **Height shift:** the residuals of the trend model at the solution cases range from –0.7 to 0.4 cm and at the check cases they range from –1.4 to 0.2 cm.

4-2 Group 2: Baselines from 3 to 7 Kilometers

Table (2): Data and results of group 2 (from 3 to 7 km base lines)

Point-point`	Dist. To base(m)	Azimuth (Deg)	ΔØ (cm)	Δλ (cm)	Result (cm)	ΔH (cm)	Result/ Dist	Area (feddan)
mm22-mm22`	3322	240	5.70	4.9	7.6	-14.3	1:44000	8095
mp32-mp32`	3424	48	-6.09	-2.7	6.7	15.3	1:52000	8599
5000-5000`	3731	44	-4.8	-3.2	5.8	9.7	1:65000	10210
m11-m11`	4045	16	-5.7	-0.5	5.7	-10.2	1:71000	12000
mm25-mm25`	4411	271	5.7	10.6	12.0	-17.0	1:37000	14270
mm86-mm86`	4827	354	-6.46	4.3	7.76	16.0	1:62000	17090
GAS3-GAS3`	5539	17	-7.1	-0.8	7.2	12.7	1:77000	22505
mm38-mm38`	6044	284	8.82	12.3	15.13	-14.5	1:40000	26795
mm53-mm53`	6048	51	-9.8	-5.3	11.2	18.2	1:54000	26830
Sokh3-Sokh3`	6496	24	-13.1	-1.7	13.2	19.0	1:50000	30950
Sokh4-Sokh4`	6634	24	-13.3	-1.8	13.5	19.7	1:50000	32280

From Table (2) it can be seen that the shift in the latitude, again the shift has negative sign when the baseline goes to the north direction. It has positive sign when the baseline goes to the south direction. The absolute shift value ranges from 4.8 to 13.3 cm. Figure (1) illustrates the absolute shift in latitude.

Concerning the shift in the longitude, the shift has negative sign when the baseline goes to the east direction. It has positive sign when the baseline goes to the west direction. The absolute shift value ranges from 0.5 to 12.3 cm. Figure (2) illustrates the absolute shift in longitude.

The horizontal resultant of the shift ranges from 5.7 to 13.5 cm. The horizontal resultant values are illustrated in Figure (3). Figure (5) illustrates the case of the horizontal shift for the second group, from 3 to 7 km.

The relative horizontal shift in its worst value is 1:37000 and the best value is 1:77000.

The absolute shift in height ranges from 9.7 to 19.7 cm. Figure (7) illustrates the absolute shifts in heights.

The trend model is computed using the data in Table (2) and the results were as follows:

- **Latitude shift:** the residuals of the trend model at the solution cases range from –2.7 to 1.3 cm and at the check cases they range from –1.4 to –1.0 cm.
- **Longitude shift:** the residuals of the trend model at the solution cases range from 1.2 to 0.8 cm and at the check cases they range from -1.2 to 6.4 cm.
- **Height shift:** the residuals of the trend model at the solution cases range from –3.2 to 3.0 cm and at the check cases they range from –4.1 to 1.4 cm.

4-3 Group 3: Baselines from 7 to 15 Kilometers

Table (3): Data and results of group 3 (from 7 to 15 km base lines)

Point-point'	Dist. To base(m)	Azimuth (Deg)	ΔØ (cm)	Δλ (cm)	Result (cm)	ΔH (cm)	Result/Dist	Area (feddan)
mm59-mm59'	8330	36	-10.3	-3.0	10.8	32.9	1:77000	50900
mp25-mp25'	10333	38	-14.9	-3.5	15.3	41.8	1:68000	78315
mb30-mb30'	12780	28	-17.7	-4.8	18.4	41.8	1:70000	119820
Sokh5-Sokh5'	14811	35	-18.3	-13.4	22.7	44.3	1:65000	160905
Sokh6-Sokh6'	14954	35	-18.7	-13.6	23.12	45.1	1:65000	164025

The shift in the latitude, again the shift has negative sign when the baseline goes to the north direction. The absolute shift value ranges from 10.3 to 18.7 cm. Figure (1) illustrates the absolute shift in latitude.

Concerning the shift in the longitude, the shift has negative sign when the baseline goes to the east direction. The absolute shift value ranges from 3.0 to 13.6 cm. Figure (2) illustrates the absolute shift in longitude.

The horizontal resultant of the shift ranges from 10.8 to 23.12 cm. The horizontal resultant values are illustrated in Figure (3). Figure (6) illustrates the case of the horizontal shift for the third group, from 7 to 15 km.

The relative horizontal shift in its worst value is 1:65000 and the best value is 1:77000.

The absolute shift in height ranges from 32.9 to 45.1 cm. Figure (7) illustrates the absolute shift in heights.

The trend model is computed using the data in Table (3) and the results were as follows:

- **Latitude shift:** the residuals of the trend model at the solution cases range from –0.1 to 0.1 cm and the check case has –8.4 cm value.

- **Longitude shift:** the residuals of the trend model at the solution cases have zero values and the check case has 13.9 cm value.
- **Height shift:** the residuals of the trend model at the solution cases range from
–0.2 to 0.2 cm and the check case has 17.7 cm value.

4-4 Group 4: Long Baseline

Table (4): Data and results of a long base line

Point-point`	Dist. To base(km)	Azimuth (Deg)	ΔØ (cm)	Δλ (cm)	Result (cm)	ΔH (cm)	Result/Dist
doml-doml`	158.055	15	-246.3	45.1	250.5	455.6	1:72000

As it is in all groups, the shift in latitude is bigger than that in the longitude. The horizontal shift after 158 kilometers is 2.5 meters and the shift in height is 4.5 meters. The relative shift in the horizontal direction 1:72000 is close to its value in the previous cases.

5- Conclusions

The effect of using the geodetic local coordinates instead of WGS-84 coordinates in the processing of the GPS observations is studied. The available data is divided into 4 groups according to the lengths of the base lines. The GPS observations are processed using WGS-84 coordinates at the base station, the coordinates of the rover points are then obtained in WGS-84. The GPS observations are processed once more using the local geodetic coordinates of the base station, the coordinates of the rover points are then obtained. The differences between the corresponding results in both cases are computed, tabulated, and graphically represented. The results showed that:

- Up to 3 km baselines: maximum horizontal shift is 4.7 cm with about 1:70000 relative shift. The vertical shift is 7.7 cm.
- From 3 to 7 km baselines: maximum horizontal shift is 15.1 cm with about 1:60000 relative shift. The vertical shift is 19.7 cm.
- From 7 to 15 km baselines: maximum horizontal shift is 23.1 cm with about 1:70000 relative shift. The vertical shift is 45 cm.

- The long base line (158 km) has 250 cm horizontal shift and 455 cm vertical shift.
- The relative horizontal shift allover the used baselines ranges between 1: 60,000 and 1:70,000. This relative shift is sufficient for most of the civil Engineering and surveying applications. On the contrary of the horizontal shift, the vertical shift is relatively big and increases rapidly with the length of the base line.
- The azimuth of the base line affects the direction (sign) and the magnitude of the results shifts in latitude , longitude and height.

A linear trend model is created to relate the obtained shift in latitude, longitude and height with the length and azimuth of the base line. The trend model is established for every group based on the lengths of the base lines.

The trend model showed that it can be used, up to 3 km base line lengths, within 0.9 cm in latitude, 0.2 cm in longitude and 1.4 cm in height. For base lines from 3 to 7 km lengths, the trend model can be used within 1.4 cm in latitude, 6.4 cm in longitude and 4.1 cm in height. For base lines from 7 to 15 km lengths, the trend model can be used within 8.5 cm in latitude, 13.9 cm in longitude and 17.7 cm in height.

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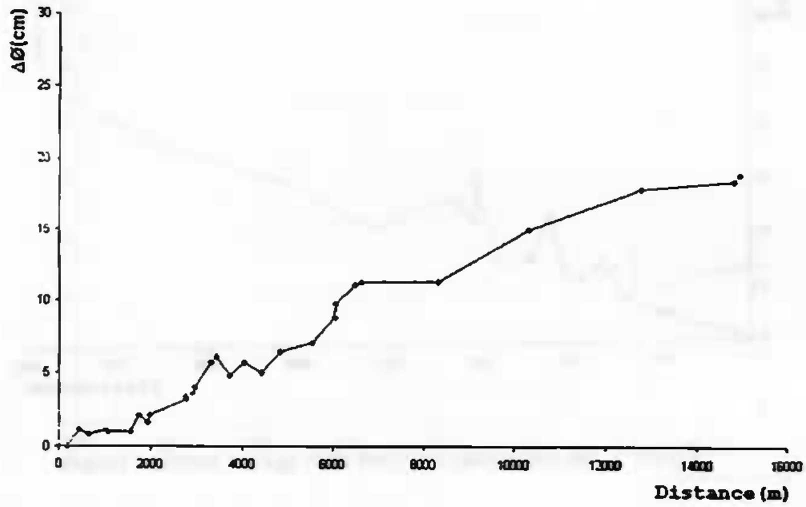

Figure 1: absolute shift in latitude against baseline length

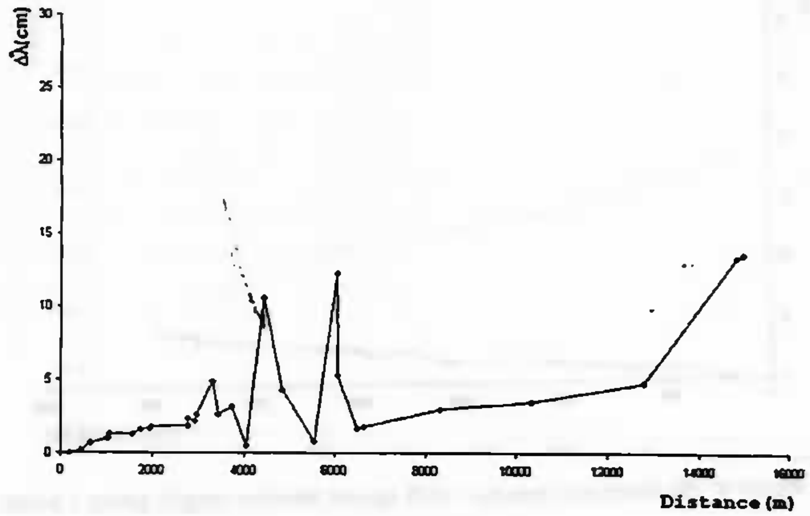

Figure 2: absolute shift in longitude against baseline length

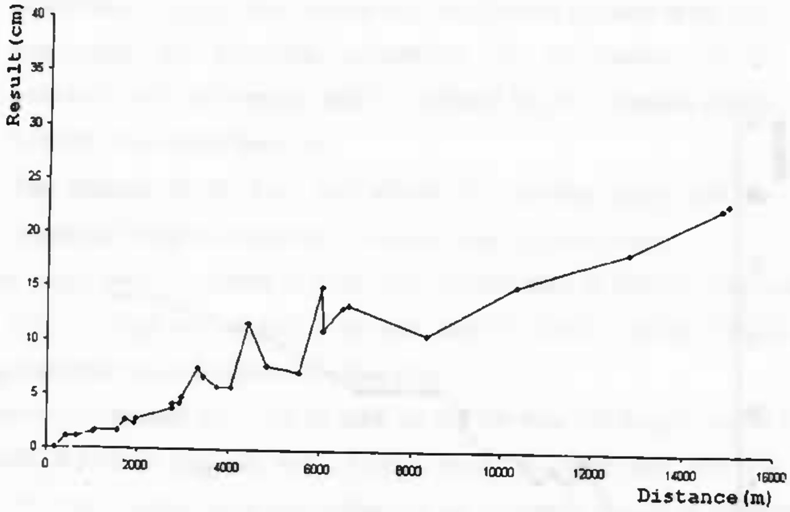

Figure 3: the horizontal resultant shift against baseline length

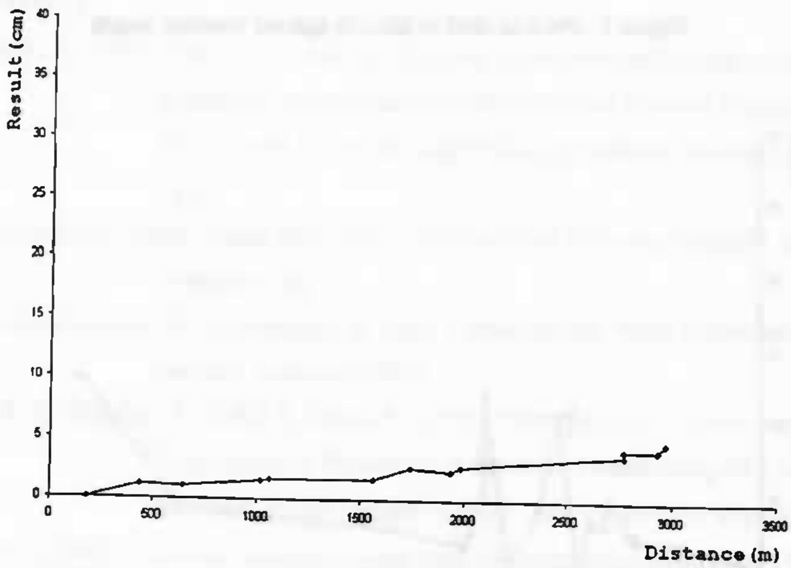

Figure 4: the horizontal resultant shift against baseline length; group 1 points

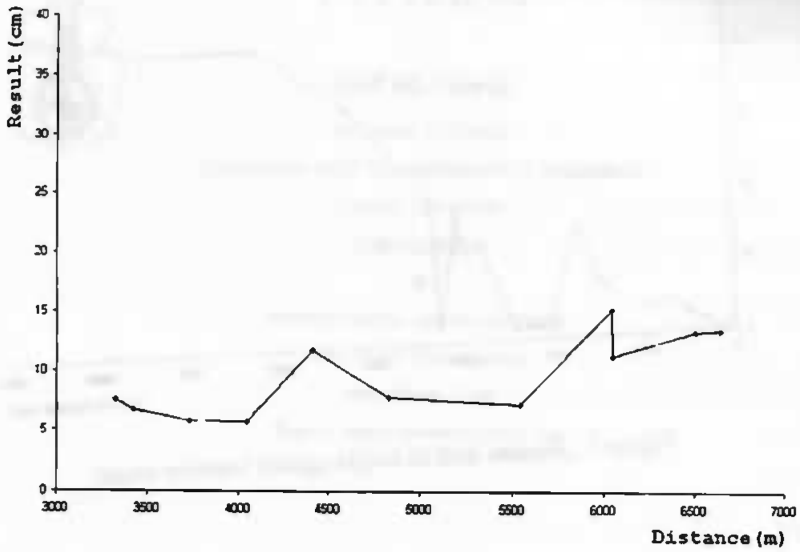

Figure 5: the horizontal resultant shift against baseline length; group 2 points

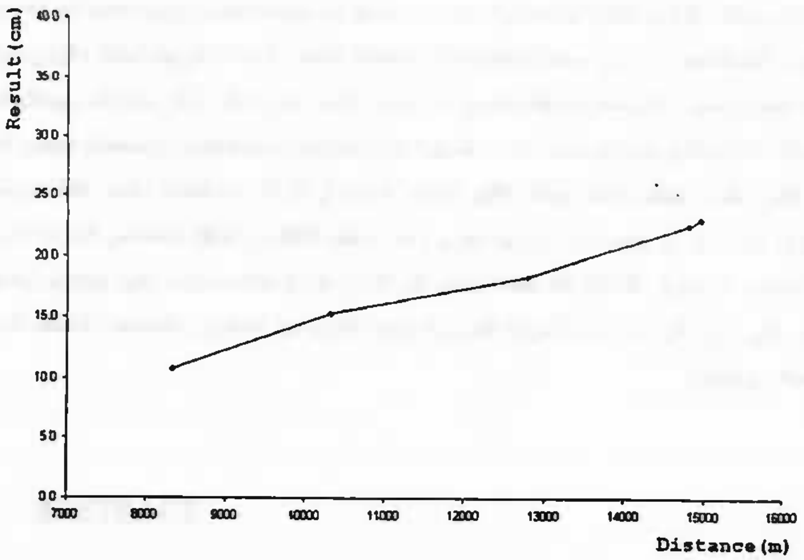

Figure 6: the horizontal resultant shift against baseline length; group 3 points

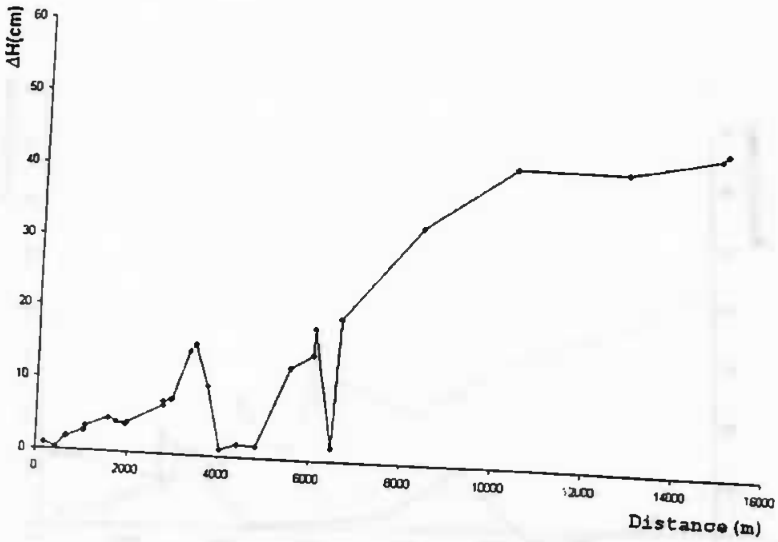

Figure 7. absolute shift in height against baseline length