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SOLAR RADIATION AND A SOLUTION FOR TRIGONOMETRIC LEVELLING ATMOSPHERIC REFRACTION

"الاشعاع الشمسي وحل الانكسار الجوى في الميزانيات المثلثية"

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الخلاصة:

الميزانية المثلثية واحده من أهم الطرق في الأعمال المساحية ولكن نتائجها تعتمد أساسا على الدقة في تعيين خطا الانكسار الجوى. ولحذف أو تقليل تأثير خطأ الانكسار الجوى المنتظم على الأرصاد يجب الأخذ في الاعتبار مصادر هذا الخطأ. يعتبر الإشعاع الشمسي مصدرا رئيسيا لخطأ الانكسار الجوى. ويهدف هذا البحث إلى شرح كيفيه تقليل تأثير خطأ الانكسار الجوى المنتظم على أرصاد الميزانيات المثلثية وذلك بتطبيق انسب معادلة رياضية تعتمد أساسا على أرصاد الطاقة الشمسية المقيسه. وقد تناول البحث بالتحليل نتائج المعادلات الرياضية المستخدمة وانسبها بالاضافه إلى التوصيات اللازمه.

ABSTRACT

Trigonometric levelling is one of the most important techniques in surveying works , however its results depends mainly on the systematic refraction error determination In order to totally or partially eliminate the influence of systematic refraction error on observations , more attention should be paid to the source of such error. Daily solar radiation is considered the main source of the refraction error .

The main objective of this paper is to demonstrate the elimination of the systematic refraction effect on trigonometric levelling by applying an appropriate mathematical model based on the available data of solar radiation. The results predicted by the new solution are presented and analyzed .

attempted to estimate the solar radiation theoretically using different models. Sometimes, this theoretical estimation of hourly values of direct, diffuse and total solar radiation data can be used when the measuring equipment's are not available .

In the last few years , Modern Technology in electronics has been used for the accurate measuring of the net and diffused solar radiation . the present paper deals only the measuring data of solar radiation .

3. Relation between atmospheric refraction effect on trigonometric levelling and solar radiation .

To obtain the best possible relation between Refraction and solar radiation several observations were carried out from sunrise to sunset during 1993 and 1994 . The observations illustrate the refraction effect for different atmospheric conditions , Also the solar radiation was recorded parallel to the trigonometric levelling observations.

All observations were measured using EDM instrument DI 20 built up one second wild theodolite T2 . The height differences between the instrument point and receiver points are obtained precisely by precise levelling . The measuring refraction error presents the difference between trigonometric height and height difference given by precise levelling

In the next part , the four sets of mathematical models for calculation the effect of atmospheric refraction are introduced .

I) Linear model . ($y = A + BX$).
ii) Logarithmic model ($y = A + B \log x$) .
iii) Exponential model ($y = A e^{B x}$) .
iv) Power function model ($y = A x^{B}$).

where; y is the atmospheric refraction effect in mm, x is the net solar radiation in cal / cm ^{2} , A and B are unknown coefficients obtained experimentally [HEER, 1985].

A FORTRAN computer program was designed to performs all computations of the field observations . It would be seen that measurements during the day time are divided into three parts from 6.0. to 11.0 , from 12 - 15.0 and from 16.0 to the end of observations . Tables (1) and (2) present the results of the four mathematical models using the field observations of the trigonometric levelling and the net solar radiation.

1. Introduction

The systematic atmospheric refraction correction in Trigonometric levelling observations is a very demanding aspect if an accuracy improvement and high precision are required . This accuracy can be only obtained , if refraction error is studied and avoided strictly . The difficulties in determining this error by using the classical meteorological parameters led to search about an alternative method .

The recent developments in electronics have led to accurate measuring of solar radiation for energy generation purposes . These devices are used in large areas all over the world . one of those stations now is existing in El-Mansoura university and data of solar radiation are available . Based on the available data of solar radiation it is possible to study the relation between the solar radiation and atmospheric refraction effect on trigonometric levelling .

The present study shows a very strong correlation between the solar radiation and atmospheric refraction which effect on trigonometric levelling This relation is studied and an appropriate mathematical model is presented Also the results of using predicted model are given and discussed .

2. Solar radiation

The amount of solar radiation on the earth's surface is attenuated by the terrestrial atmosphere . On clear days, it may reach the ground level after having been deflected up to 15% of it's original value out side the atmosphere [M. SAYEGH , 1983] .The attenuation is caused by some effects namely :-

1- scattering by molecules much smaller than the wave length of radiation .

2 - scattering by aerosols (Dust , smoke , pollen , ete.) of size comparable to or larger than the wave length of radiation .

3 - scattering and absorption by cloud masses .

4 - selective absorption by gases present in the atmosphere and particularly by O_2 , O_2 , H_2O , CO_2 .

In this way. the solar radiation reaching the earth consists of direct and diffuse radiation . Owing to the importance of knowing accurately the solar radiation on the earth's surface and to the unreliability of available equipment, to measure a solar radiation several authors [STANTON,1975]

Table (1) Summary of the four models solution (date: 1993).

Date	Linear best fit $y = a + bx$				Logarithmic $y = a + b \ln x$			
	All day	1st part 6-10	2nd 10-2AM	3rd part 2-6.00	All day	1st part	2nd part	3rd part
8-3	1.54+3.76x	0.87−2.70x	3.99+2.17x	1.99−4.48x	5.46+1.71lnx	3.68+0.87lnx	6.33+2.2 lnx	6.22+1.72lnx
9-3	1.36+2.71x	3.45-1.01x	1.34+3.15x	0.13+4.96x	3.96+1.03lnx	2.56 -0.36lnx	4.66+2.83lnx	3.49+1.03lnx
15-3	3.42+0.43x	3.04+1.68x	3.46−0.11x	3.08+0.99x	4.06+0.25lnx	4.66+0.77lnx	3.55+0.17lnx	4.72+0.97lnx
16-3	3.76+0.29x	2.53+0.83x	4.37-0.27x	3.59+2.24x	4.22+0.42 lnx	3.23+0.19lnx	4.07-0.3lnx	6.45+1.72lnx
Average	2.52+1.80x	2.47+1.05x	3.29+1.29x	2.2+3.17x	4.43+0.92 lnx	3.38+0.37lnx	4.65+1.23lnx	5.22+1.36lnx
7-6	0.39+1.99x	-0.28+3.03x	1.39+0.96x	0.26+2.18x	2.73+1.06lnx	2.92+3.29lnx	2.1+1.80lnx	2.19+0.77lnx
8-6	2.48+0.01x	1.87+0.74x	7.58-3.75x	2.28+0.05x	2.52+0.11lnx	2.68+0.67lnx	3.76+4.64lnx	2.53+0.19lnx
27-6	1.52+0.3x	3.92-1.33x	6.38-3.29x	0.12+1.56x	1.93+0.29lnx	2.49 - 0.78lnx	3.16-4.19lnx	1.27+0.4lnx
14-7	1.15+0.81x	4.04-1.77x	0.79+1.11x	0.48+2.26x	2.1+0.62lnx	2.18-1.87lnx	1.78+1.7lnx	2.51+0.99lnx
15-7	0.87+1.17x	2.24-0.68x	-0.96-2.75x	0.85+1.19x	2.12+.55lnx	1.50 - 0.61lnx	1.95+2.9lnx	1.92+0.44lnx
average	1.28+0.86x	2.36-0.01x	3.04-.45x	0.8+1.45x	2.28+0.53lnx	2.35+0.14lnx	2.55-0.4lnx	2.08+0.56lnx
2-9	1.79+1.08x	0.99−1.56x	14.84-8.04x	0.92+3.9x	3.05+0.72lnx	2.6 − 1.03lnx	7.13-10.73lnx	4.22+1.32lnx
3-9	1.70+0.43x	2.27-0.14x	-1053+8.8x	2.32-2.1x	2.13+0.08lnx	2.77+0.22lnx	2.15+1.95lnx	0.63-0.61lnx
4-10	1.75+0.75x	1.93+0.71x	2.16+0.38x	1.26+0.9x	2.59+0.40lnx	2.69+0.63lnx	2.49+0.61lnx	2.43+0.36lnx
average	1.85+1.14x	2.25+0.88x	2.83+1.22x	1.54+1.84x	3.1+0.62lnx	2.81+0.38lnx	3.23+0.45lnx	3.24+0.76lnx

Date	Exponential $y = a e^{bx}$				Power $y = a x^{b}$			
	All day	1 St. part	2 nd part	3 rd-part	All day	1 St. part	2 nd part	3 rd part
8-3	failed	$1.18e^{1x}$	$3.99e^{.39x}$	failed	failed	$2.65x^{.31}$	$6.09x^{.4}$	failed
9-3	failed	$3.2e^{-0.36x}$	$1.13e^{1.2x}$	failed	failed	$2.29x^{-0.15}$	$4.19x^{1.14}$	failed
15-3	failed	$2.98e^{.14x}$	$3.48e^{-0.01x}$	failed	failed	$4.42x^{.18}$	$3.48x^{-.01}$	failed
16-3	failed	$2.57e^{0.14x}$	$3.15e^{.15x}$	failed	failed	$2.84x^{.01}$	$3.2x^{.02}$	failed
average	failed			failed	failed			failed
7-6	failed	$0.89e^{.98x}$	$0.52e^{1.0x}$	failed	failed	$2.49x^{1.08}$	$1.25x^{1.10}$	failed
8-6	failed	$2.05e^{0.1x}$	$12.59e^{-1.3x}$	failed	failed	$2.41x^{.13}$	$3.34x^{-1.62}$	failed
27-6	failed	$3.97e^{-.5x}$	$26.76e^{-1.7x}$	failed	failed	$2.23x^{.32}$	$3.82x^{-2.54}$	failed
14-7	failed .	$4.63e^{0.8x}$	$0.77e^{.6x}$	failed	failed	$1.93x^{-0.87}$	$1.41x^{.98}$	failed
15-7	failed	$2.18e^{-.4x}$	$1.63e^{1.5x}$	failed	failed	$1.39x^{-0.39}$	$1.63x^{1.51}$	failed
average	failed			failed	failed			failed
2-9	failed	$1.53e^{.38x}$	$4.04e^{-.6x}$	failed	failed	$2.25x^{.19}$	$10.5x^{-3.5}$	failed
3-9	failed	$2.54e^{-0.02x}$	$0.01e^{4.5x}$	failed	failed	$2.52x^{.10}$	$0.17x^{6.33}$	failed
4-10	failed	$3.56e^{-.8x}$	$2.14e^{3.1x}$	failed	failed	$1.82x^{.6}$	$3.6x^{-1.2}$	failed
average	failed			failed	failed			failed

Table (2) summary of the four models solution (date: 1994).

Date	Linear best fit y = a + bx				Logarithmic y = a + b ln x			
	All day	1st part 6-10	2nd 10-2AM	3rd part 2-6.00	All day	1st part	2nd part	3rd part
11-2	2.52+1.8x	2.47+1.05x	1.05 + 4.1x	0.16+4.8x	3.78+0.48lnx	4.0-0.4lnx	3.73 -0.6lnx	2.21+0.81lnx
12-2	1.62+3.15x	2.7+0.92x	3.46+ 0.11x	1.66+1.5x	1.82+0.94lnx	5.3+1.4lnx	2.16+0.2lnx	2.48+0.4lnx
7-3	3.42+0.45x	3.04+1.7x	2.43+0.11x	3.0+1.0x	2.12+0.36lnx	0.07+0.8lnx	2.4+1.1lnx	1.46+0.75lnx
7-3	2.87+1.6x	2.1+0.98x	4.21+0.32x	0.47+3.78x	4.01+0.84lnx	0.11+0.7lnx	4.6+1.6lnx	3.14+0.02lnx
Average	3.36+1.75x	2.7+1.16x	2.71+11.6x	1.32+3.77x	2.18+0.65 lnx	2.37+0.62lnx	2.47+0.58lnx	2.32+0.49lnx
18-6	2.1+1.9x	3.4-1.2x	1.4+3.12x	1.88-3.8x	4.64+0.52lnx	2.14+0.34lnx	1.94+0.54lnx	4.06+1.06lnx
7-7	3.0+0.36x	0.85 + 2.8 x	4.21+0.32x	2.3+1.7x	1.0+0.14lnx	2.79-0.88lnx	1.88+0.58lnx	3.01+0.84lnx
8-7	2.48+0.12x	3.04 + 2.51x	4.17-1.6x	1.99-0.99x	3.51+0.4lnx	2.14+0.93lnx	0.88-0.34lnx	1.31+0.21lnx
3-8	3.32+0.48x	2.53 + 2.82x	1.34-0.27x	4.04+0.22x	0.64+0.83lnx	4.11+1.1lnx	3.14+1.06 lnx	2.44+0.75lnx
average	2.72+0.71x	2.45 + 1.73 x	2.78+0.57x	2.55-2.87x	2.79+0.47lnx	1.82+0.36lnx	2.02+0.46lnx	2.7-0.7lnx
11-9	2.6+1.02x	1.54 + 4.1x	3.04+2.1x	0.41+3.6x	2.06+0.09lnx	3.11+0.6lnx	1.6+0.62lnx	1.92+0.44lnx
2-10	2.82+3.2x	2.31 + 0.43x	0.82+2.1x	2.1+3.1x	3.61+1.6lnx	2.34+0.8lnx	6.0+0.18lnx	2.18+0.8lnx
3-10	1.16+0.43x	0.87 + 1.4x	-0.71+2.7x	1.4+0.81x	4.0+1.1lnx	4.06+0.04lnx	2.8+0.84lnx	0.93+0.33lnx
average	2.19+1.55x	1.74 + 1.9 x	1.05+2.3x	1.3+2.5x	3.2+0.93lnx	2.17+0.45lnx	3.13+0.54lnx	1.67+0.52lnx

Date	Exponential $y = a e^{bx}$				Power $y = a x^{b}$			
	All day	1 st part	2 nd part	3 rd-part	All day	1 st part	2 nd part	3 rd part
11-2	failed	$4.12e^{0.11x}$	$2.75e^{-.4x}$	failed	failed	$2.64x^{0.96}$	$5.5x^{0.51}$	failed
12-2	failed	$1.08e^{-0.2x}$	$4.11e^{-.98x}$	failed	failed	$9.84x^{-0.14}$	$4.12x^{-0.02}$	failed
7-3	failed	$3.34e^{2.1x}$	$1.07e^{.64x}$	failed	failed	$5.29x^{0.6}$	$4.56x^{-1.06}$	failed
7-3	failed	$4.86e^{.61x}$	$3.35e^{2.11x}$	failed	failed	$4.19x^{0.89}$	$3.73x^{-0.24}$	failed
avarage	failed			failed	failed			failed
18-6	failed	$2.54e^{2.1x}$	$5.1e^{-1.9x}$	failed	failed	$4.08x^{0.14}$	$1.34x^{0.23}$	failed
7-7	failed	$4.36e^{.11x}$	$4.01e^{-1.4x}$	failed	failed	$3.81x^{.24}$	$3.91x^{0.92}$	failed
8-7	failed	$4.81e^{-7.4x}$	$3.91e^{1.1x}$	failed	failed	$4.12x^{.74}$	$4.01x^{-2.31}$	failed
3-8	failed	$5.14e^{.63x}$	$4.12e^{-1.x}$	failed	failed	$2.18x^{-.91}$	$3.97x^{-.46}$	failed
average	failed			failed	failed			failed
11-9	failed	$2.14e^{.83x}$	$1.07e^{-.43x}$	failed	failed	$3.87x^{-.48}$	$2.48x^{.48}$	failed
2-10	failed	$2.76e^{.22x}$	$4.8e^{-.12x}$	failed	failed	$4.12x^{-.14}$	$3.12x^{.77}$	failed
3-10	failed	$1.13e^{1.4x}$	$4.39e^{-.65x}$	failed	failed	$2.39x^{.06}$	$4.42x^{.75}$	failed
average	failed			failed	failed			failed

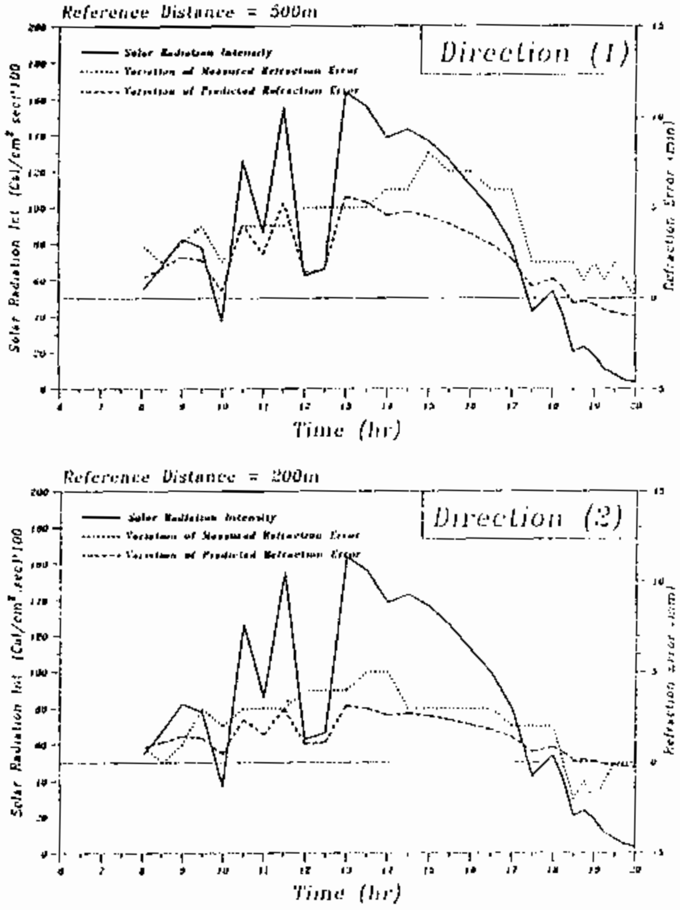

Fig.(1- a,b) Variation Of Solar Radiation, Measured Refraction Correction and Predicted Refraction Correction

Date: 15. 7. 1993.

Time	Direction (1) Reference Distance = 500m				Direction (2) Reference Distance = 200m				Meteorological Parameters		
	Observed Distance (m)	σ (mm)	Refraction Error (mm)		Observed Distance (m)	σ (mm)	Refraction Error (mm)		Temperature (C)	Pressure mmbar	Solar Radiation Cal/cm
			Measured	Predicted			Measured	Predicted			
8:00	498.215	01	+3	+1.1	189.499	03	+1	+0.8	35.5	990.45	0.5382
8:30	498.214	01	+2	+1.6	189.498	04	00	+1.1	36.5	990.32	0.6700
9:00	498.215	01	+3	+2.3	189.499	03	+1	+1.4	39.5	990.45	0.8268
9:30	498.216	03	+4	+2.1	189.501	05	+3	+1.3	37.1	990.32	0.7800
10:00	498.214	00	+2	+0.1	189.500	05	+2	+0.5	32.0	990.32	0.3705
10:30	498.216	01	+4	+4.1	189.501	03	+3	+2.4	37.0	987.25	1.2675
11:00	498.216	01	+4	+2.1	189.501	00	+3	+1.5	35.5	986.59	0.8580
11:30	498.216	01	+4	+5.3	189.501	04	+3	+3.0	36.8	989.25	1.5680
12:00	498.217	01	+5	+1.5	189.502	07	+4	+1.0	34.0	989.25	0.6240
12:30	498.217	00	+5	+1.6	189.502	04	+4	+1.1	35.1	989.25	0.6630
13:00	498.217	00	+5	+5.6	189.502	05	+4	+3.2	33.9	989.25	1.6380
13:30	498.217	01	+5	+5.3	189.503	06	+5	+3.0	35.2	989.25	1.5600
14:00	498.218	02	+6	+4.6	189.503	04	+5	+2.6	32.5	989.25	1.3845
14:30	498.218	00	+6	+4.8	189.501	00	+3	+2.7	33.0	989.12	1.4313
15:00	498.220	01	+8	+4.5	189.501	03	+3	+2.6	34.5	986.59	1.3650
15:30	498.219	02	+7	+4.1	189.501	04	+3	+2.4	33.5	986.59	1.2597
16:00	498.219	00	+7	+3.5	189.501	04	+3	+2.1	32.8	985.25	1.1310
16:30	498.218	01	+6	+3.0	189.501	05	+3	+1.8	32.0	985.25	0.9945
17:00	498.218	01	+6	+2.2	189.500	03	+2	+1.4	32.0	986.59	0.7995
17:30	498.214	01	+2	+0.7	189.500	02	+2	+0.6	31.3	986.59	0.4290
18:00	498.214	01	+2	+1.1	189.500	03	+2	+0.8	31.8	987.92	0.5421
18:15	498.214	01	+2	+0.6	189.498	01	00	+0.6	30.5	987.92	0.4095
18:30	498.214	00	+2	-0.3	189.496	01	-2	+0.1	29.7	988.19	0.2028
18:45	498.213	01	+1	-0.1	189.497	03	-1	+0.2	29.2	989.25	0.2340
19:00	498.214	01	+2	-0.3	189.496	01	-2	+0.1	28.3	989.92	0.1872
19:15	498.213	00	+1	-0.7	189.497	02	-1	-0.1	27.7	990.45	0.1092
19:30	498.214	00	+2	-0.8	189.498	01	00	-0.1	27.5	990.59	0.0780
19:45	498.213	00	+1	-0.9	189.498	00	00	-0.2	27.0	990.85	0.0468
20:00	498.212	00	00	-1.0	189.498	00	00	-0.2	26.5	990.99	0.0351

Table (3-1) Observed Distances, Refraction Error And Meteorological Parameters

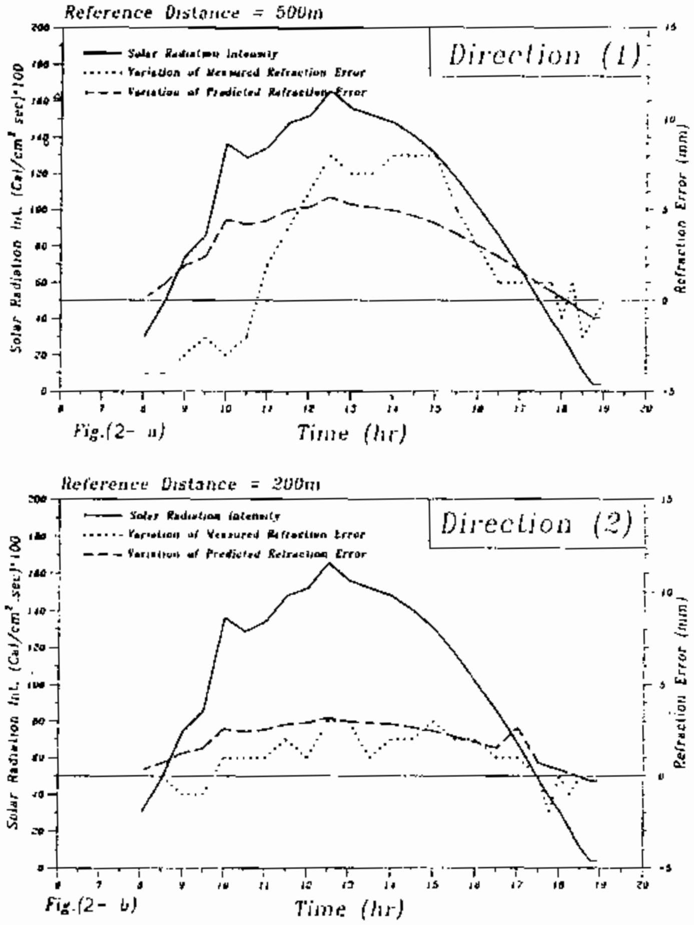

Fig.(2- a)

Fig.(2- b)

Fig.(2- a,b) Variation Of Solar Radiation, Measured Refraction Correction and Predicted Refraction Correction

Date: 3. 9. 1993.

Time	Direction (1) Reference Distance = 500m				Direction (2) Reference Distance = 200m				Meteorological Parameters		
	Observed Distance (m)	σ (mm)	Refraction Error (mm)		Observed Distance (m)	σ (mm)	Refraction Error (mm)		Temperature (°C)	Pressure mmbar	Solar Radiation Cal/cm
			Measured	Predicted			Measured	Predicted			
8:00	498.208	01	-4	+0.1	189.498	00	00	+0.3	24.80	994.18	0.2925
8:30	498.208	01	-4	+0.9	189.498	00	00	+0.7	25.70	994.18	0.1875
9:00	498.209	04	-3	+1.9	189.497	00	-1	+1.3	27.50	993.25	0.7410
9:30	498.210	02	-2	+2.4	189.497	02	-1	+1.5	27.70	991.92	0.8580
10:00	498.209	01	-3	+4.5	189.499	03	+1	+2.6	28.00	993.25	1.3650
10:30	498.210	01	-2	+4.2	189.499	00	+1	+2.4	30.00	993.25	1.2870
11:00	498.214	02	2	+4.4	189.499	05	+1	+2.5	30.50	992.98	1.3455
11:30	498.216	01	4	+5.0	189.500	03	+2	+2.8	31.30	992.32	1.4820
12:00	498.218	02	6	+5.1	189.499	03	+1	+2.9	31.00	991.92	1.5210
12:30	498.220	00	8	+5.7	189.501	05	+3	+3.2	33.20	991.65	1.6575
13:00	498.219	02	7	+5.3	189.501	05	+3	+3.0	33.20	991.52	1.5600
13:30	498.219	01	7	+5.1	189.499	02	+1	+2.9	33.50	990.59	1.5210
14:00	498.220	02	8	+5.0	189.500	01	+2	+2.8	33.70	989.92	1.4820
14:30	498.220	01	8	+4.7	189.500	01	+2	+2.7	33.50	989.92	1.4040
15:00	498.220	01	8	+4.3	189.501	01	+3	+2.5	33.80	989.92	1.3065
15:30	498.217	00	5	+3.7	189.500	02	+2	+2.2	33.00	989.92	1.1700
16:00	498.215	02	3	+3.1	189.500	02	+2	+1.8	32.30	990.19	1.0140
16:30	498.213	02	1	+2.4	189.499	02	+1	+1.5	32.30	990.19	0.8580
17:00	498.213	01	1	+1.7	189.499	00	+1	+1.1	34.80	989.92	0.6825
17:30	498.213	00	1	+0.9	189.498	01	00	+0.7	31.20	989.52	0.4875
17:45	498.213	01	1	+0.5	189.496	01	-2	+0.5	30.80	989.52	0.3900
18:00	498.211	00	-1	+0.2	189.498	01	00	+0.4	30.20	990.59	0.3120
18:15	498.213	00	1	-0.2	189.497	00	-1	+0.2	29.50	990.59	0.2145
18:30	498.210	01	-2	-0.6	189.498	01	00	-0.1	29.20	990.59	0.1170
18:45	498.211	00	-1	-1.0	189.498	00	00	-0.2	28.50	990.59	0.0390
19:00	498.213	00	0	-1.0	189.498	00	00	-0.2	28.00	990.59	0.0390

Table (3-2) Observed Distances, Refraction Error And Meteorological Parameters

Table (1) provides a summary of the four model solutions . From this table , it is clear that the logarithmic and linear models may give a reliable solution Where the most important is that the exponential and power function are failed to give a reasonable solution . Moreover , the strong correlation between the net solar radiation and atmospheric refraction effect on trigonometric leveling observations are valid .

As shown from the table the results obtained from the linear mathematical model is considered quit bigger than that of the logarithmic form solution . Based on the above results , in order to obtain the appropriate mathematical solutions for calculating the refraction effects on trigonometric levelling by using solar radiation data, the logarithmic model solution should be taken . On the other hand , the expected model from the author's point of view , to have the following logarithmic form as :

$$y = A + B \text{ Log } x$$

Where A and B values are determined and illustrated in the above Figures (1-a) ,(1-b) , (2-a) , (2-b) and table (3-a & b) present the samples of measuring refraction and predicted refraction error by using logarithmic model.

4. Conclusions

It is clear that , logarithmic form provides better results than other forms . This study show the atmospheric refraction correction on trigonometric levelling can be obtained efficiently by using solar radiation. In order to obtain the practical form of such correction, it is necessary to investigate a lot of trigonometric levelling observations including additional information about the net radiation.

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