Re-measuring and Processing of the Israeli GNSS-Based 3-rd Level Geodetic Control Network

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Key words: GNSS Network, Processing, Adjustment.

SUMMARY

According to the new Regulations that come into effect in 2007, the Israeli coordinate system consists of three levels and is based on GNSS measurements solely. The first level is named G0 and consists of 18 stations of Active Permanent Network (APN). The second level is the Geodetic-Geodynamic Network of Israel G1. It consists of 150 control points that were built according to high technical specifications to ensure their geotechnical stability. The third level is Geodetic Control Network named G2. At present it includes 778 control points and needs re-measuring to match the accuracy standards required by the new Regulations.

New control points are being added to the G2 network to replace the destroyed points and to fill in the gaps. In addition, the benchmarks on which the GNSS measurements are feasible but were not performed are also being measured. They are included into the G2 network and added to the Israel Undulation Model (ILUM) in order to make it more comprehensive and precise. Altogether the G2 network includes about 1200 control points (about 1 control point per 20 square km).A short-term measurement cycle to be performed within two years is expected to enhance the network consistency.

The network consists of 67 loops. Each loop includes at least 2 control points of the G1 network, the mean baseline being 4.5 km, the average number of control points in a large loop being 40 and the average number of control points in a small loop being 10. Each control point is determined by at least two independent observations and at least 2 baselines. The time of one measurement depends on the length of the baseline. The processed baseline error does not exceed 3 mm both in horizontal and vertical components. The loop misclosure error does not exceed 1 ppm in the horizontal plane and 2 ppm in the vertical plane.

The adjustment error of the minimally constrained loop does not exceed 10 mm in the horizontal plane and 25 mm in the vertical plane.

Re-measuring results were also used to test the reliability of the first version of the official Israeli Geoid Undulation Model ILUM 1.0. Areas have been identified where the model needs to be improved and completed. The new version of the model that takes into account the results of the re-measuring is being developed.

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1 INTRODUCTION

According to the new Regulations that come into effect in 2007, the Israeli National Grid (plane coordinate system) will be based on the permanent GPS stations of Israel (Steinberg, 2006). The primary class G is to be established and measured by Survey of Israel only. It consists of 3 levels as follows:

G0- the array of 18 (might extend up to 24 in the future) GPS active permanent network stations of Israel (APN).

G1- an existing network of about 150 control points, built especially for geodynamics monitoring (Ostrovsky, 2001).

G2 - a network of about 1200 control points with easy access, at a density of about 1 point per 20 square kilometers. A major part of those points are existing benchmarks which are suited for GNSS measurements. At present it includes 778 control points and needs re-measuring to match the accuracy standards required by the new Regulations. The details about the new National Grid based on the APN stations were described in (Steinberg and Even-Tzur, 2005).

New control points are being added to the G2 network to replace the destroyed points and to fill in the gaps. In addition, the benchmarks on which the GNSS measurements are feasible but were not performed are also being measured. They are included into the G2 network and added to the Israel Undulation Model (ILUM) in order to make it more comprehensive and precise. A short-term measurement cycle to be performed within two years is expected to enhance the network consistency.

This paper describes the steps of performing, the re-measuring, the processing and adjustment of the G2 order network

2 SELECTION OF THE POINTS OF THE G2 ORDER NETWORK.

The G2 order network includes three groups of points. The first, most numerous group, which is the basis of the network, consists of the points constructed in 1994-2001 within the framework of the undulation project. The project was developed to build the precise geoid in Israel (Papo, Sharni and Forrai,1998). These points were used both to determine the horisontal coordinates and to construct the geoid-ellipsoid separations model. The second group comprises the layer of the control points that were used to base the GPS projects made since 1998. These points did not belong to the first group. The third group consists of the benchmarks tnat could be used as base points for positioning, that is, it is possible to mount

GNSS antennae at these benchmarks. Neither the second nor the third group of points was previously included into the undulation project. Inclusion of these benchmarks into the Israel Undulation Model (ILUM) makes possible to increase the accuracy of the model and/or widen the territory on which it can be applied.The use of these points makes geodetic measurements more convenient for surveying.Within the framework of the project several new points were constructed in order to condence the existing network. These base points would facilitate measurements, especially for the cadaster projects.

3 ORGANIZATION OF THE FIELD MEASUREMENTS

First of all, the inspection of the existing points was performed to estimate their physical condition and their suitability for mounting the GNSS antennae. Whenever some of the points were found destroyed, they were replaced by the new ones. The requirements for the receivers and measurements were formulated so as to minimize the possible errors. For example, the measurements were performed by dual-frequency GNSS receivers with the p-code. The epoch interval equals 5 sec. The baseline was measured by two identical receivers with the same type of antenna. The devices in which the antenna and the receiver form one unit were not used. The distance between the antenna and the receiver in the time of measurement was at least 3 meters. These actions were taken to avoid the errors due to the human factor. A special type of log was developed to avoid errors in the recordings of the names and measurement conditions of the stations. For each type of antenna used in the project special forms were developed which helped to minimize the errors of the measurement of the antenna height on the station.

A special set of maps was issued to back up the project. Fig 1a and 1b show fragments of maps for different regions of Israel.

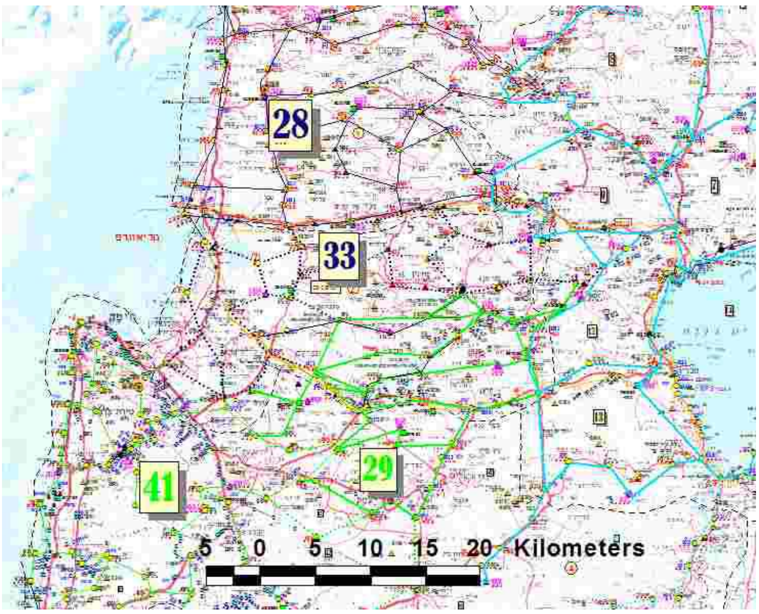

Fig 1a. The project map of the Northern part of Israel (fragment).

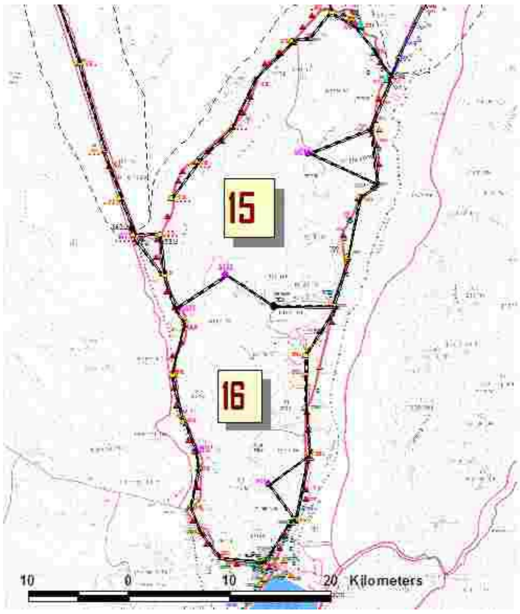

Fig 1b. The project map of the Southern part of Israel (fragment).

4 DESCRIPTION OF THE FIELD MEASUREMENTS

The project of measuring 1200 network points consists of 67 main loops, each of which may consist of one or more elementary loops. An average number of points in such elementary loop is about 15. Each loop was measured by two receivers only. Transfer of the receivers was made so that every station of the loop was determined from at least two occupations and by means of at least two baselines. The height of the antenna had to be changed in different occupations of one station. The direction of the movement along the loop remained the same during the measurement of the loop. In Fig 1a loop No28 is an example of a large loop consisting of several loops.The examples of small loops No15 and No16 are represented in the Fig 1b. Each of them consists of one elementary loop.

The time of the occupation while measuring the baseline less than 10 km long had to be at least 40 min. If the length of the baseline was more than 10km and less than 20 km, the occupation time had to be at least 60 min. The occupation time on the G1network point had to be at least 1h 30min, irrespective of the length of the baseline.Whenever possible, the G1 order points are connected to the G0 stations, hence if the baseline length was more than 20 km and less than 40km, the occupation time reached up to 2 hours; if the baseline length was more than 40km, the occupation time was at least 3 hours. The measurements could not be performed if PDOP was greater than 4. The cut off angle was 10 degrees.

5 PROCESSING

Each loop was processed separately. The baselines connecting G1 points with permanent stations were processed using precise ephemeris. Only double difference fixed solutions were accepted for further use. Loop horisontal closure was at least $7_{mm}\sqrt{n}$, loop height closure was at least $14_{mm}\sqrt{n}$, where n is a number of baselines in a loop. If this accuracy was not achieved, the additional measurements were performed and, if necessary, the entire loop was measured again. Table 1 represents data on closures for two of the loops (they are fragments of the large loops No28 and No29 respectively). One of the loops (28_06) does not answer the criterion of horisontal accuracy and demands additional treatment.

The total number of the processed baselines was about 5000. All the processing was performed by means of the Trimble Total Control (TTC) program.An example of the processed loop is represented in Fig 2.

Loop Number	28_06	Allowed accuracy	29_07	Allowed accuracy
Number of Baselines	15		10	
Total Length (m)	53125.315		30048.375	
North(m)	**0.036**	0.027	0.008	0.022
East(m)	-0.001		0.003	
Height (m)	0.017	0.056	-0.010	0.044
Precision (ppm)	0.744		0.441	
Ratio	1 / 1344262		1/2265078	

Table 1. Example of the loops closures.

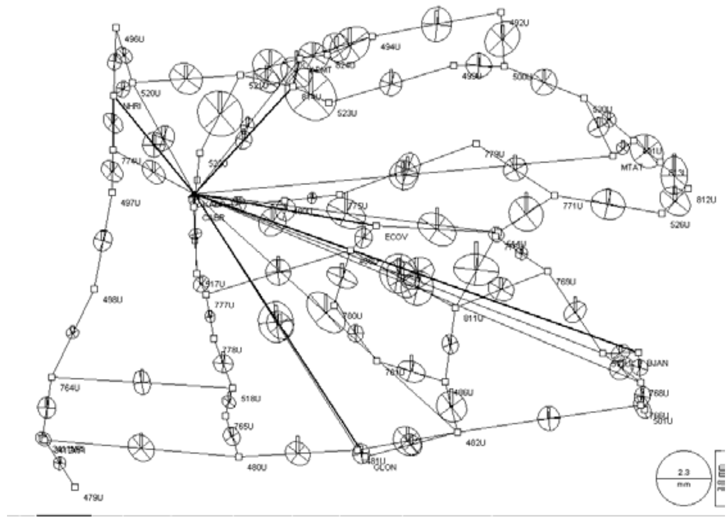

Fig 2. Processing of the loop No28

	σX (mm)	σY (mm)	σZ (mm)
average for 279 baselines	1.6	1.5	1.4
standard deviation	0.6	0.5	0.5
minimal value	0.5	0.3	0.3
maximal value	3.7	3.0	3.2

Table 2. Results of the baselines processing for the fragment of the network.

6 PRELIMINARY ADJUSTMENT OF THE NETWORK

Before the adjustment of the whole network, each loop was adjusted separately with one control point of the G0 order. Coordinate values of other points of G0 (if available) and the coordinate values of G1 were compared with the known ones. The residuals obtained make possible not only to draw a conclusion about the actual accuracy of the network but also to identify and eliminate blunders, if any.The next step is to connect several loops into the larger fragments of the network and to adjust each fragment, first, as minimally constrained, then as totally constrained.

As an example we can take a fragment consisting of 279 baselines and 186 points. The fragment shown in Fig. 1a comprises 4 large loops (Nos 28, 29, 33, 41) and covers the area of 3500 square km. The average baseline length in this fragment is 5.880 km. Table 2 shows the results of the baseline processing of the fragment and Table 3 shows the residuals of the coordinates of the G0/G1 order points obtained by the adjustment of the minimally constrained network. In Table 3 the five upper lines show the G0 order stations BSHM, KATZ, CSAR, GILB and KABR , and the rest are of the G1 order. The fixed G0 order point is BSHM. The similar Table 4 shows the residuals of the G1 order coordinates with respect to 5 constrained stations of G0 order The residuals are the differences between computed values and those obtained in the year 2001 (Ostrovsky, 2001).The G1 order point CSON needs special treatment.

	Residuals (m)		
Name	Lattitude	Longitude	Ellipsoidal Height
BSHM	***0.000***	***0.000***	***0.000***
KATZ	0.005	-0.036	-0.022
CSAR	0.002	0.008	0.011
GILB	-0.002	0.008	-0.024
KABR	-0.005	0.015	0.004
ADMT	0.009	-0.013	0.015
ATLT	-0.007	0.000	0.017
AVTL	-0.008	-0.010	-0.011
BJAN	-0.013	-0.017	0.002
CABR	-0.017	-0.018	-0.008

CSON	**-0.015**	**-0.011**	**-0.040**
ECOV	-0.010	0.003	-0.020
GLON	-0.010	-0.012	-0.012
HZON	-0.008	-0.021	0.014
KRML	-0.002	-0.014	0.009
KRMV	-0.008	0.005	-0.006
KRTV	-0.010	-0.005	0.006
MRKA	-0.008	-0.008	-0.001
MTAT	0.003	0.010	0.020
NHRI	-0.012	-0.018	0.003
NTFA	-0.010	0.009	0.010
PARK	-0.002	0.008	-0.014
YAFI	-0.026	-0.017	-0.016
ZPRI	-0.021	-0.009	-0.001
average	*-0.009*	*-0.008*	*-0.003*
Std	*0.008*	*0.012*	*0.015*
Max	*0.009*	*0.015*	*0.020*
Min	*-0.026*	*-0.036*	*-0.040*

Table 3. Residuals of the coordinates of the G0/G1 order points with respect to the minimally constrained network adjustment .

	Residuals (m)		
Name	Latitude	Longitude	Ellipsoidal Height
BSHM	***0***	***0***	***0***
CSAR	***0***	***0***	***0***
GILB	***0***	***0***	***0***
KABR	***0***	***0***	***0***
KATZ	***0***	***0***	***0***
ADMT	0.010	0.008	0.015
ATLT	-0.007	0.000	0.016
AVTL	-0.008	-0.008	-0.010
BJAN	-0.008	-0.019	-0.001
CABR	-0.011	-0.021	-0.013
CSON	**-0.015**	**-0.011**	**-0.040**
ECOV	-0.005	0.000	-0.024
GLON	-0.006	-0.013	-0.015
HZON	-0.009	0.001	0.025
KRML	-0.002	-0.014	0.009
KRMV	0.016	0.015	0.016
KRTV	-0.010	-0.005	0.007
MTAT	0.017	0.016	0.019

PARK	0.012	0.011	0.013
MRKA	-0.008	-0.008	-0.001
NHRI	-0.007	-0.021	-0.001
NTFA	-0.010	0.010	0.010
YAFI	-0.026	-0.019	-0.011
ZPRI	-0.019	-0.012	0.005
average	*-0.008*	*-0.008*	*-0.002*
Std	*0.007*	*0.009*	*0.014*
Max	*-0.002*	*0.010*	*0.025*
Min	*-0.026*	*-0.021*	*-0.040*

Table 4. Residuals of the coordinates of the G1 order points with respect to the constrained network adjustment

Microsearch GeoLab, V2001.9.20.0				
2-D and 1-D Station Confidence Regions (95 percent):				
Order	Value	Semi_axis		Vertical
		Major	Minor	
G1: 19 points	average	0.013	0.011	0.015
	max	0.018	0.016	0.023
	min	0.006	0.006	0.006
G2: 162 points	average	0.021	0.019	0.023
	max	0.040	0.035	0.041
	min	0.006	0.005	0.007

Table 5. Results of the G1 and G2 order points adjustment.
The G0 order points are constrained

Table 5 presents the results of the adjustment of the whole fragment. The constrained points are of the G0 order. The final step in adjustment of the network will be to obtain the G2 order network coordinates by fixing the coordinates of G0 and G1 order points.This step will be possible only after all the fragments are combined into the whole network. For the fragment under consideration the temporary coordinates of the G2 order points were obtained by the network adjustment with the fixed G0 and G1 order points .(The point CSON was not used as a known fixed point). The total number of the points with the fixed coordinates is 23. The total number of the G1 order points in the fragment is 162. 109 of them were re-measured and 53 obtained for the first time.Out of these 53 points 16 are benchmarks. All the adjustment was performed by means of the Microsearch GeoLab Program version V2001.9.20.0. These coordinates will temporarily be used as low class S1control points until the adjustment for the entire network has been completed. Similarly, step by step, following the evaluation and the preliminary adjustment, all the fragments of the network are being merged into the total network.

7 TESTING THE VALIDITY AND RELIABILITY OF THE ISRAELI UNDULATION MODEL

Each time the benchmark was measured by means of GNSS, the value of its orthometric height obtained by using the Israeli Undulation Model (ILUM1.0) was compared with the value obtained by levelling.The principles that lay in the basis of the model (Tuchin, 2006) proved correct. The model produced reasonable results. It predicted accuracies which correspond to the residuals, as shown in Table 6 for 16 benchmarks measured in the fragment. All these benchmarks were not part of the undualtion model. In Fig 3 these benchmarks are marked by blue squares among the points of the model marked by the red circles.

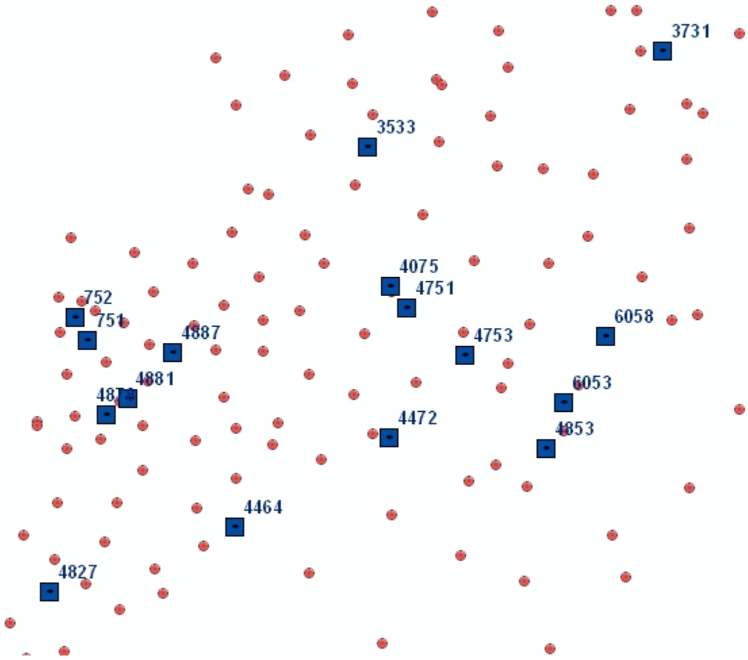

Fig 3. The benchmarks that were measured by means of GNSS measurements in the loops Nos 28,29,33,41

Benchmark Name	Model Accuracy	Height Residuals
4881	0.038	-0.021
751	0.045	-0.011
3731	0.054	-0.010
4878	0.045	-0.003
4887	0.036	0.003
4464	0.062	0.004
4827	0.058	0.005
4472	0.052	0.006
6058	0.040	0.009
4853	0.058	0.010
752	0.039	0.010
4075	0.036	0.016
4751	0.049	0.017
4753	0.051	0.020
6053	0.050	0.026
3533	0.058	0.034
	average	*0.007*
	stdev	*0.014*
	max	*0.034*
	min	*-0.021*

Table 6. Comparison of orthometric heights values that were calculated using ILUM1.0 with levelled values.

8 CONCLUSION

The ultimate goal of the Survey of Israel is to define the cadastral boundaries with the accuracy of 5 cm at 95 percent confidence level (Steinberg, 2001). To reach this goal was to establish new national grid,based on permanent GNSS stationzs equipped with virtual reference stations (VRS) options. Control points that are to be base for cadastral works provide the abilitty of measuring with accuracy of up to one centimeter level. In order to obtain their coordinates the new measurements project was developed in Survey of Israel in the year 2005. Now the measurements are finished and first results of the proceccing and coordinates computation wereobtained. The field material check and analysis make shure that the quality of most of measurements is high enough to solve the problem of renewing national coordinate sistem. The project will be finished up to the end of year 2009. At that time the Survey of Israel provide the surveyours with accurate, reliable,consistent national grid based on active permanent network.

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