Determination of Geoid and Transformation Parameters By Using GPS On The Region of Kadinhani in Konya

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INTRODUCTION

- Three dimensional networks can be constituted also with satellite techniques (as GPS). The Cartesian coordinates (X;Y;Z) and the ellipsoidal coordinates (f , ?, *h*) of points are obtained in the WGS-84. With satellite techniques to establish and densification three dimensional networks and is more rapid, more accuracy, fewer difficult than terrestrial techniques

- National geodetic networks were being formed in order to horizontal and vertical location separately up to now. Constitution of three dimensional national networks has been begun with techniques of satellite geodesy as GPS, GLONASS observations. Thus the problem of transformations to global datum and combining geodetic networks has been appeared.

INTRODUCTION

- In this study a test area had been chosen for transformation problem and determination geoid. This test area is in Kadinhani region. The local geodetic network on the region of Kadinhani in Konya had been established according to national coordinate system and this network have been used up to now.

- Then for densification the geodetic points of this test network had been established in the proper distribution for using of the persons concerned. The transformation parameters and geoid undulations had been determined

GPS and NATIONAL COORDINATE SYSTEM

- General Command of Mapping (GCM) is the national mapping agency of Turkey. GCM is responsible for the basic geodetic control Networks, 1:25.000 and smaller scale map production.

- The Turkish National Datum 1954 (TND54) had been made up by GCM between 1934-1954 years as a result of intensive geodetic studies throughout the country. The Mesedag had been accepted as a datum of the Turkish National Geodetic Network and this datum adapted to European Datum 1950 (ED-50).

- The vertical datum had been made up according to geoid. Antalya meraograph station had been chosen origin point for vertical datum. Then orthometric height of control points had been determined on this datum.

GPS and NATIONAL COORDINATE SYSTEM

- The new geodetic network had been required for local and regional deformation on the national basic geodetic horizontal network which was established by the conventional techniques. So Turkish National Fundamental GPS Network (TUTGA) has been established, to provide reliable and robust geodetic network infrastructure for current and future geo-based data collection technologies (Table 1).

- TUTGA were established between 1997 and 1999 and it has been realized based on an agreement among General Directorate of Land Registry and Cadastre and General Commander of Mapping. It has been designed as four dimensional (4D). Designing concept is sufficient for all type of small scale, low resolution digital mapping and data collection applications. Datum of TUTGA is International Terrestrial Reference Frame 1996 (ITRF96) at epoch 1998.00. Therefore it is the part of global network. Which means any data collected or map produced based on TUTGA has a global meaning and is globally identified and valid (Çelik et al, 2004).

GPS and NATIONAL COORDINATE SYSTEM

Table 1. Technical Specifications of TUTGA

Datum	ITRF96
Ellipsoid	GRS80
Number of Control Stations	594
Common with National Geo. Net.	91
Common with Geodynamic Net.	53
Common with Levelling Net.	181
Common with SLR Stations.	5
Range of Control Stations	25-70 km
Density of Control Stations	1315 km2/stn

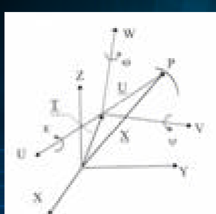
TRANSFORMATION BETWEEN TWO REFERENCE COORDINATE SYSTEM

- To fulfill the requirements for transforming data from one reference frame or coordinate system to another is usually resolved by applying coordinate transformation. So transformation parameters can be computed when there are known coordinates of common points at every two system. These transformation parameters define a model relation between two reference coordinate system. There are several transformation models such as Bursa-Wolf Molodensky-Badekas, Veis Model, Thomson-Krakiwsky Model, Helmert Similarity Transformation, Affine transformation. (Hofmann-Wellenhof et al, 1997).

THREE-DIMENSIONAL TRANSFORMATION MODELS

- Seven parameters are needed to describe the relation between two geodetic reference coordinate system, three translation parameters and three rotations between the coordinate axes and the scale parameter.
- When coordinate transformations between geodetic reference systems are applied, small values are expected for the rotation and the scale parameters. Thus, assuming rotation parameters of the order of a few seconds of arc, the following form of the 3D similarity transformation is often used (King. et al, 1985).

THREE-DIMENSIONAL TRANSFORMATION MODELS



$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} Tx \\ Ty \\ Tz \end{bmatrix} + (1+k)R \begin{bmatrix} U \\ V \\ W \end{bmatrix}$$

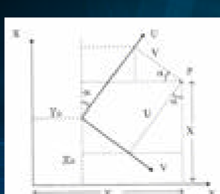
- The mathematical model of the Bursa-Wolf method (Hofmann-Wellenhof et al, 1997).

- The relationship between 3D coordinate systems

TWO-DIMENSIONAL TRANSFORMATION MODELS

- Two-dimensional similarity transformation expresses relationship between two system, two-dimensional coordinate system. The aim of the similarity transformation is to prevent deformation of shape. In this transformation model, the coordinate axes are perpendicular to each other in the own system and it is assumed that scale factor is same on the x axis and y axis in the own system. There is shifting, rotation and scale difference between two coordinate system as (U,V) and (X,Y).

TW0-DIMENSIONAL TRANSFORMATION MODELS



$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} X_0 \\ Y_0 \end{bmatrix} + k \begin{bmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} U \\ V \end{bmatrix}$$

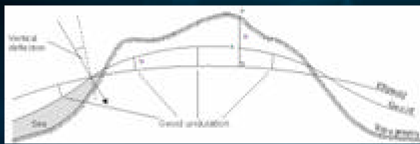
The mathematical model of two dimensional transformation(Hofmann-Wellenhof et al, 1997).

- The relationship between 2D coordinate systems

RELATIONSHIP BETWEEN ELLIPSOIDAL AND ORTHOMETRIC HEIGHTS

- If it is talked about height of a point on Earth surface, one can understand it describes relationship between point of interest and geoid. This relationship can be interpreted in both geometric and physical ways. Geometric height of a point on Earth surface is a distance described along the plumb line between this point and geoid (Demirel, 1984).
- The geoid is that level surface of the Earth's gravity field coincides with the mean ocean surface (Torge, 1980). It is that equipotential surface (surface of fixed potential value) which coincides on average with mean sea level

RELATIONSHIP BETWEEN ELLIPSOIDAL AND ORTHOMETRIC HEIGHTS



- The geoid surface is more irregular than the ellipsoid of revolution often used to approximate the shape of the physical Earth, but considerably smoother than Earth's physical surface. The geometrical separation between it and the reference ellipsoid (as GRS-80) is called the geoid undulation. The orthometric height is the distance H along a line of force from a given point P at the physical surface of an object to the geoid
- Ellipsoidal height (h) of a point on physical earth as P is equal to the distance between the point P and the point where ellipsoid is touched by the line that passes from the point P and is perpendicular to the ellipsoid.

RELATIONSHIP BETWEEN ELLIPSOIDAL AND ORTHOMETRIC HEIGHTS

- The geometric relationship between the reference ellipsoid -- the datum for ellipsoidal heights and the geoid is illustrated in above figures and defined by the simple equation:
- **N = h – H**
- where **N** is the geoid-ellipsoid separation, or simply the geoid height, or geoid undulation, **h** is the ellipsoidal height and **H** is the orthometric height.

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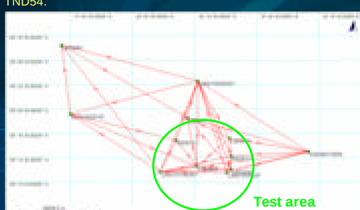
THE APPLICATION

- The study area is Kadinhani district within Konya province, total area 150 square km. There is 2 TUTGA points, 4 stations graded by C1, 4 stations graded by C2 appropriately to the Big Scale Map and Map Information Production Regulations (BSH&MIPR) in the study area. There is 54 stations graded by C3 with 4 station graded by C2 in the test area. In the test area there is 22 stations which their coordinates are known in TND54.



The fundamental network

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THE APPLICATION

- In the fundamental network, the first section GPS observations had been made on 25-26 July 2003 and the second section GPS observations had been made on 03 December 2003. In the first section, 6 dual frequency Javad receiver and JPSODYSSEY_I antenna integrated into receiver had been used. In the second section, 6 dual frequency Ashtech UZ-12 receiver and Marine L1-L2 antenna had been used. Approximately 2 hours static GPS observation data are recorded with the sampling rate of 10 seconds and with a 15-degree elevation cutoff.
- In the test area, GPS observations had been made on 27-29 June 2006. For GPS observations 2 dual frequency Leica GX1230 receiver and AX1201 antenna, 2 dual frequency Leica SR9500 receiver ve AT302 antenna, 2 single frequency Ashtech Promark receiver and ASH110454 antenna had been used in the fundamental network. Approximately 30 minutes rapid-static GPS observation data are recorded with the sampling rate of 5 seconds and with a 15-degree elevation cutoff.

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THE APPLICATION

- The GPS observations were processed and adjusted in Leica Geoffice 1.0 commercial GPS software. The adjustment had been made appropriately to BSH&MIPR by using the Cartesian coordinates of two TUTGA stations which were fixed at 2003.7068 epoch in ITRF datum. After adjustment, yearly velocity vectors of points, which were graded by C1 and C2, had been estimated by interpolation method (epoch 1998.00). Then the test network which consisted of graded by C3 stations had been adjusted at reference epoch 1998.00.
- The horizontal transformation from ITRF to TND54 had been made by using 2D Helmert similarity transformation model. 22 stations were used in transformation. Root means square of transformation is ±4.3cm (table 2)

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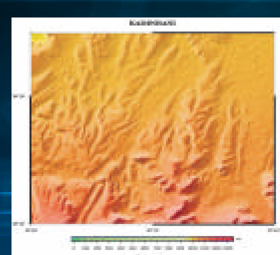
THE APPLICATION



- Topograhy of Kadinhani region, created by GMT (Wessel and Smith, 1998).

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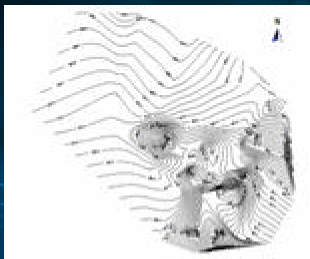
THE APPLICATION



Topograhy of test area

THE APPLICATION

Table 2. Transformation parameters between ITRF and TND54

Rotation origin	Y0:	430294.057 m.	
	X0:	4236263.581 m.	
Parameter	Value	R.m.s.	Dim.
Shift dy	28.141	0.0092	m
Shift dx	182.899	0.0092	m
Rotation about Z	0.892	0.3361	["]
Scale	12.095	1.6296	[ppm]
Max. North Errror	11.40 cm		
Max. East Error	9.17 cm		
Min. North Errror	0.09 cm		
Min. East Error	0.49 cm		

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- The orthometric heights of 13 stations are known. Spirit leveling has been carried out to determine orthometric heights of unknown heights of stations. During the spirit leveling, Sokkisha automatic level, staffs with level tube and staff shoes were used. Heights of the 25 points in study area were determined with respect to the point of L28G210 and L28G521. the geoid undulations were determined by using multiquadratic surface fitting. The geoid undulation equation computed surface fitting is given as below

$$N = A_1 + A_2Y + A_3X + A_4Y^2 + A_5XY^2 + A_6XY + A_7X^2 + A_8X^2Y + A_9 + X^2Y^2$$

Root means square of surface fitting is ± 2.9 cm (Table 3).

- Then the stepwise method from SKI 2.3 GPS processing software were used by using height transformation to determine orthometric heights. The regional geoid undulation N=36.787m was obtained from this method (Table 4).

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THE APPLICATION

Table 3. Bi-quadratic polynom surface cofficients and height errors

A 1 =	36.4679 m
A 2 =	-0.0000352149
A 3 =	0.0000001517
A 4 =	-0.0000000018
A 5 =	0.0000000000
A 6 =	0.0000000023
A 7 =	0.0000000023
A 8 =	0.0000000000
A 9 =	0.0000000000

STATION ID	V(cm)
L280517	-0.8
L280518	0.6
L280519	1.4
L280520	-3.4
L280521	3.2
L28G203	-0.6
L28G204	0.3
L28G210	-0.1
L28G211	-0.2
L28G553	0
L742	-2.5
L784	1.7
RS231/1	0.3

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Table 4. The height transformation computed by stepwise method

Number of common points:		13		
Height parameters:	-0.00001023	0.00001105	-36.787m	
Inclination of height reference plane in X-direction:			-0.00059 degree	
Inclination of height reference plane in Y-direction:			0.00063 degree	
Point Id	GPS [m]	orig. [m]	transf. [m]	res. [m]
L280517	1181.237	1144.843	1144.782	0.061
L280518	1187.240	1150.826	1150.771	0.055
L280519	1288.083	1251.633	1251.607	0.026
L280520	1233.960	1197.433	1197.477	-0.044
L280521	1164.386	1127.908	1127.878	0.030
L28G203	1323.402	1286.867	1286.878	-0.011
L28G204	1401.703	1365.198	1365.270	-0.072
L28G210	1115.231	1078.650	1078.703	-0.053
L28G211	1074.961	1038.310	1038.279	0.031
L28G553	1070.529	1033.915	1033.926	-0.011
L742	1119.398	1082.810	1082.804	0.006
L784	1111.124	1074.584	1074.511	0.073
RS231/1	1104.941	1068.187	1068.277	-0.090
Mean transformation accuracy for 13 points: dHm:			±0.05m	

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CONCLUSIONS

- In this study. because study area is small, two dimensional transformation parameters for horizontal coordinates (easthing and northing) between ITRF-96 to TND54 was obtained. The maximum error is 11.4 cm and 9.2 cm resptectively northerly and easterly. So these parameters appropriate for the Big Scale Map and Map Information Production Regulations . These transformation parameters can be used for various cadastral plans and points, which are known coordinates in ITRF or TND54.

- The root mean square of differences between stepwise method and levelling is ±4.6 cm and between surface fitting and levelling is ± 7.4 cm. According to results the stepwise method may be widely used. If a surface fitting method is used to obtain orthometric heights from ellipsoidal heights, it is necessary to have some known points in the both height systems in an almost certain density. It is also required to know the variations of geoid undulation to reach the best point distribution in the surface fitting.

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