DETERMINATION OF ORTHOMETRIC HEIGHTS WITH REAL TIME KINEMATIC SURVEYING, KONYA SAMPLE

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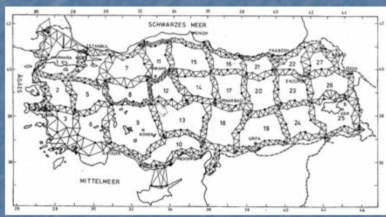
CONTENT

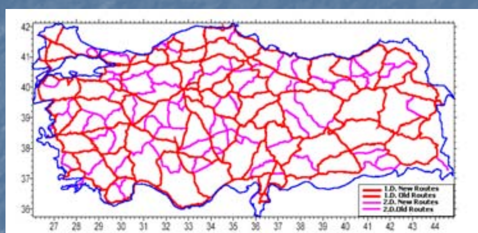
INTRODUCTION

- The national geodetic networks were established separately for horizontal and vertical control up to now. Horizontal datum is a collection of specific points on the Earth that have been identified according to their precise northerly or southerly locations (latitude) and easterly or westerly locations (longitude).



- Datums used in Turkey for ϕ, λ:
  - Turkish National Datum 1954 (ED50)
  - International Terrestrial Reference Frame (ITRF96, Ref. Epoch 1998.00)

- The vertical datum is a collection of specific points on the Earth with known heights either above or below mean sea level. Near coastal areas, mean sea level is determined with a tide gauge. In sea areas away from the shore, mean sea level is determined by the shape of the geoid. The height of any vertical control point in Turkey is referred to the tide gauge station in Antalya.

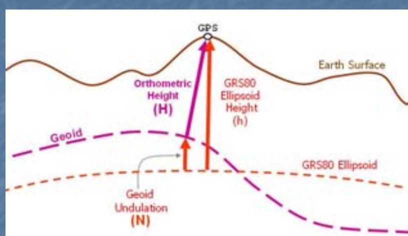


- Datums for H (Orthometric Height):
  - Turkish National Vertical Control Network (TNVCN-99)
- Datum for h (Ellipsoidal Height):
  - GRS80 ellipsoid

- Three dimensional networks can also be established with satellite techniques. The Cartesian coordinates (X;Y;Z) and the ellipsoidal coordinates (ϕ, λ, h) of points are obtained in the WGS-84. When compared to conventional methods, three dimensional networks can be established more easily, more rapidly and more accurately by using satellite techniques.

- In this study, the usage of geoid undulations at real time kinematic (RTK) surveying using GPS observations is investigated. Geoid undulations at the points in the area of interest were determined with respect to RTK and using regional geoid model (rgm) file derived from multi-quadratic interpolation technique. Orthometric heights known and RTK results from study were then compared with each other.

RELATIONSHIP BETWEEN ELLIPSOIDAL AND ORTHOMETRIC HEIGHTS



N=h-H

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 as geoid undulation. The orthometric height (H) is the distance along a line of force from a given point (P) at the physical surface of an object to the geoid.

Ellipsoidal height difference is determined by GPS, but computation of geoid undulation (N) difference requires some additional processes. The basic geoid undulation determination techniques are:

1. Astro-geodetic method.
2. Geopotential models,
3. Surface gravity techniques (i.e. Stokes' Integral),
4. Geometric or interpolation methods.

MULTIQUADRATIC INTERPOLATION TECHNIQUE

$$N_{trend}(x,y) = a_0 + a_1 y + a_2 x + a_3 xy + a_4 y^2 + a_5 xy^2 + a_6 x^2 a_7 x^2 y + a_8 x^2 y^2$$

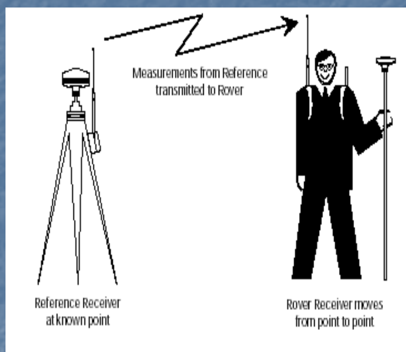
The multiquadratic interpolation technique was suggested by Hardy. The purpose of this interpolation technique is to define the best matching surface to the region of interest by a single function using the entire control points known. It is also an analytic solution technique. For the application of the technique, a trend surface must be drawn. It is appropriate to use first and second degree polynomials as a trend surface in this technique.

$$N(x,y) = N_{trend} + \sum_{i=1}^{n} C_i \left[(x_i - x)^2 + (y_i - y)^2\right]^{1/2}$$

n stands for the items control points, and
ci are the coefficients calculated by means of known N(x,y) values of the control points

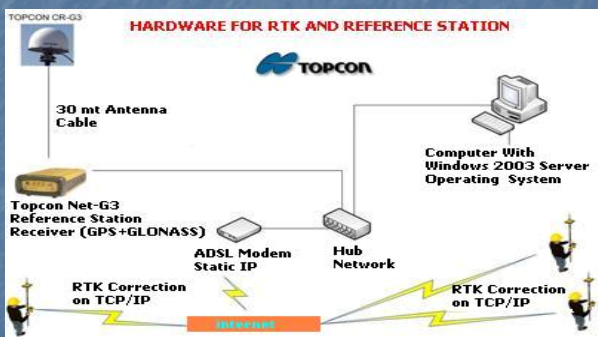
REAL TIME KINEMATIC TECHNIQUE AND SELECTED REFERENCE STATION IN KONYA FOR RTK

- The base station re-broadcasts the phase of the carrier that it measured, and the mobile units compare their own phase measurements with the ones received from the base station. This allows the units to calculate their relative position to millimeters, although their absolute position is accurate only to the same accuracy as the position of the base station.



The typical nominal accuracy for these dual-frequency systems is 1 cm (±2ppm) horizontally and 2 cm (±2ppm) vertically. Also these values may change according to capabilities of GPS receiver, communication, distance between base receiver and the rover receiver, distance-dependent biases (orbit bias), ionosphere and troposphere bias.

- Konya Municipality started to operate single reference station for RTK positioning, whereby users can receive the corrections within the municipality boundary. Topcon NET G3 reference station receiver was employed. This reference station is controlled by a central server. TopNET 7.12 Reference Station software is used for data processing.



FIELD MEASUREMENTS AND RESULTS

- Field works were done according to big scale map and map information production regulations for Konya metropolitan city, in autumn 2007.
- 6 Turkish National Fundamental GPS Network (TUTGA) points,
- 8 stations graded as C1
- 24 stations graded as C2
- 1218 stations graded as C3
- Total area is approximately 1800 km^2
- 4 Leica System 1200 receivers and 4 Javad GPS receivers and their antennas
- Observations with 10" interval within 30-minute period, totally for 1369 points
- The measurements were completed in 25 days in May and June 2007
- Pinnacle 1.0 for processing and adjusting

- Geometric Levelling
  - 3 Topcon DL-101C, Topcon DL-102C and Sokkisha SDL30
  - Measurements completed in 5 months between April and July 2007
  - The geometric leveling network has 2843 height difference and 1885 stations
  - 6 points whose coordinates were known in Turkish National Vertical Control Network (TNVCN-99)
  - Root mean square (rms) of leveling adjustment is ±7.56 mm

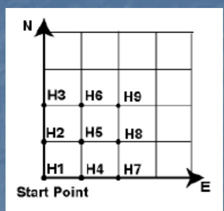
- The second order-nine parameter multi-quadratic surface was fitted to the topography by using well distributed 1175 control points.
- rms of surface is ± 4.5 cm

$$N = a_1 + a_2 y + a_3 x + a_4 y^2 + a_5 xy^2 + a_6 xy + a_7 x^2 + a_8 x^2 y + a_9 x^2 y^2$$

Coefficients of multi-quadratic surface equation

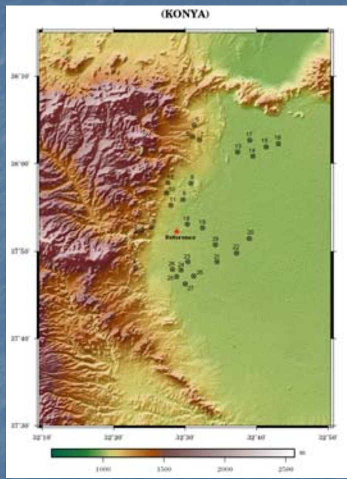
- a1 = 35.848719452232800
- a2 = -0.000006229550258
- a3 = 0.000005929540559
- a4 = 0.000000000004456
- a5 = -0.000000000000024
- a6 = -0.000000000230247
- a7 = -0.000000000108540
- a8 = 0.000000000000025
- a9 = 0.000000000000000

- Geoid undulations of 30″x30″ spacing grid points were computed from coefficients of multi-quadratic surface to use in regional geoid model file (*.rgm) for Topcon RTK GPS receivers.



LAT,LON, n_row, n_column, step_lat,step_lon, geoid_direction, ellipsoid;	*37 43 30, 32 21 00, 45, 50, 00 30, 00 30, NE, GRS80;*
H1 H2 H3	*35.807 35.815 35.823*
H4 H5 H6	*35.785 35.795 35.805*
H7 H8 H9	*35.764 35.776 35.788*

- The orthometric heights of 34 points obtained by Topcon GR3 double frequency receiver have been compared with original heights in the chosen test area.
- Occupation time 9 seconds
- 29 points were used for the orthometric height testing, rms of 5 points >3σ
- Accuracy ± l.8 cm in easting, ± 2 cm in northing using RTK



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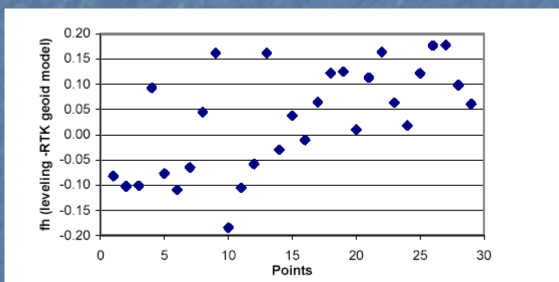
- The height difference between the highest and lowest points in the test area was approximately 377.4 meters.
- The height differences were in the range of ± 18 cm



	Average	Average of Absolute values	Maximum Discrepancy	Minimum Discrepancy	RMS σ
Orthometric	0.031 m	0.094 m	0.184 m	0.010 m	0.107 m
Ellipsoidal	0.008 m	0.039 m	0.101 m	0.002 m	0.052 m

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- There are no systematic errors in ellipsoidal height determination by GPS. The difference between orthometric heights estimated by leveling adjustment and the ones obtained by RTK with geoid model (the geoid model + GPS ellipsoidal heights) can be attributed to
  - random noise in the values of h, H, N in Konya Vertical Control network
  - Datum inconsistencies and other possible systematic distortions in the three height data sets (e.g. long-wavelength systematic errors in N, distortions in the vertical datum due to an over constrained adjustment of the leveling network, deviation between gravimetric geoid and reference surface of the leveling datum).

CONCLUSIONS

- The feasibility of determining real-time orthometric heights by RTK at the cm-level accuracy is shown in Konya sample.
- The RTK GPS survey technique may be an efficient and accurate alternative to the leveling techniques currently being used.
- On average, the results agree to within 10 cm. The regional geoid model was estimated from second degree multi-quadratic surface in this study.
- According to ellipsoidal heights, the deviations of orthometric heights are twofold. The estimated surface may be incompatible with topography.
- However, further tests on the larger network with a greater number of stations may provide more insight to RTK with geoid model method as an alternative to leveling.

- THANK YOU FOR LISTENING

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