FIG WORKING WEEK 2004

Istanbul Technical University
Geodesy Division

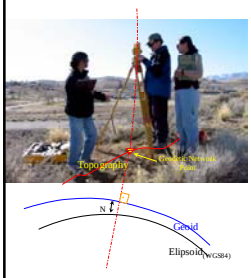
Precise Local Geoid Determination to Make GPS Technique More Effective in Practical Applications of Geodesy

Bihter Erol & Rahmi N. Çelik
Istanbul/ Turkey

Presented by Dr. Rahmi N. Çelik
TS7 Reference Frame in Practice

Athens, Greece
22-27 May 2004
"The Olympic Spirit in Surveying"

INTRODUCTION



*GPS provide 3D precise positioning

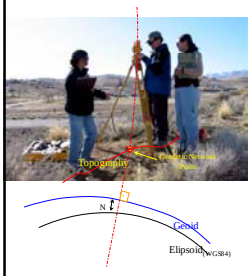
$(X, Y, Z)_{WGS84}$
$(\varphi, \lambda, h)_{WGS84}$
$(E, N, h)_{WGS84}$

*However, surveyors need height from the geoid (H: Orthometric height) since physical phenomenon occurs regarding geoid not ellipsoid.

*Therefore to transform the height from the ellipsoid to the geoid, geoid heights (N) has to be obtained.

May 24, 2004

INTRODUCTION #Continue-1#



*One of the way of obtaining (N) is to have sprit levelling measurements.

Advantage of sprit levelling measurement is its precision

However it is hard to carry out and needs long measurement time

Therefore it is not convenient for most practical geodetic purposes especially after GPS technology

* Therefore having precise geoid model is important within the working area

- for GPS based geodetic infrastructure
- for efficient 3D precise GPS surveying for the economy of GPS surveying

May 24, 2004

Geoid Modelling: A General View

Depending on data availability and accuracy requirements, there are two principle approaches for determining geoid models, which utilizes to transform GPS ellipsoidal heights to orthometric heights.

These approaches include

- gravimetric method and
- interpolation between geometrically derived geoid heights using the reference points three dimensional coordinates and orthometric heights have been determined according to GPS and levelling measurements.

May 24, 2004

Geoid Modelling: A General View #Continue-1#

By the extensive use of GPS technique with geodetic aims, great interest has been collimated to the precise determination of local/regional geoid with an aim to replace levelling measurements with GPS surveys,

In a relatively small area, the local geoid can be determined by a combination of GPS derived heights and levelling heights (Geometric approach),

May 24, 2004

Geoid Modelling: A General View #Continue-2#

From GPS derived heights (h) and levelling heights (H) at some points called as reference points, geoid heights (N) (geoid undulations) are calculated according to basic relation,

$$N = h - H$$

The geoid heights at any other GPS measurement points can be interpolated analytically or graphically as being upon to the known geoid heights of reference points.

This procedure can be carried out with *transformation*, *pointwise interpolation* or *surface interpolation* (and by this way describing the geoid as an analytical surface).

May 24, 2004

Geoid Modelling: A General View #Continue-3#

The geometric method has been mostly preferred for the model used in practical applications of geodesy, i.e. for large scale map production, engineering projects etc.

There are several factors that affect the accuracy of geoid model determined according to geometric approach. These are;

Distribution and number of common reference stations (GPS/Levelling Stations)

The accuracy of GPS derived ellipsoidal heights (≈±3.5 cm) and the accuracy of levelling heights (H) (≈±5 mm/km)

Characteristic of the geoid surface

Modeling method: it is impossible to say that a unique method works properly for local geoid models in different areas

May 24, 2004

Geoid Modelling: A General View #Continue-4#

So, it has to be given an effort to determine the most appropriate geoid model for a local area by trying different modelling methods.

There are different kinds of interpolation techniques used for modelling the geoid heights.

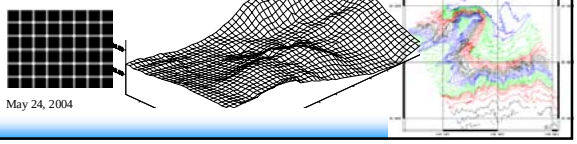
May 24, 2004

Surface Fitting for Geoid Modelling

Mainly the interpolation is handled according to three approaches:

These are ;

- pointwise (i.e. interpolation with weighted average),
- simultaneously with a function (i.e. interpolation with polynomials),
- patchwise (i.e. interpolation with summation of surfaces)



May 24, 2004

Surface Fitting for Geoid Modeling #Continue-1#

- In this study, which is presenting as a case study in here, the geoid model of the working area was expressed with fifth degree polynomial.
- This polynomial constitutes the trend function (deterministic part) of a collocation problem.
- The geoid undulations of interpolation points were determined according to Least Squares Collocation (LSC) method.
- Collocation is the most general form of the adjustment process which includes least squares adjustment, filtering and prediction (interpolation, extrapolation) steps with in a combined algorithm.

May 24, 2004

Case Study : Geoid Modelling in Turkey

- "Turkish Geoid 1999A" the last one;

In some part of the country, this national regional geoid model can not satisfy the accuracy, which is necessary for most of the routine geodetic applications. So, the necessity of studying on local geoid model appeared because of the national geoid model as a solution method.

The regions where local geoid modeling studies were carried out in Turkey. The squares give an idea about the relative sizes of the coverage areas of the geoid models. Izmir is pointed out with an arrow.

Case Study : #Continue-1#

İzmir Local Geoid Model

As it is well known, using more intensive and homogeneous distributed data and concerning the changes of geoid surface with in this limited area while modelling the geoid results increased accuracy of the model. With these aims, there are several local geoid modelling studies were carried out. The locations of these study areas are indicated on the Turkey map in previous figure.

İzmir is one of these areas. This metropolitan city is located in the west of Turkey just beside of the Aegean Sea.

The area of the study covers 50x45 km² area of this region.

For modelling the geoid of this area, a fifth degree polynomial was used as a trend function.

May 24, 2004

Case Study : #Continue-2#
İzmir Local Geoid Model

$$N(X,Y) = \sum_{k=0}^{5} \sum_{\substack{j=k-i \\ i=0}}^{k} a_{ij} y^i x^j$$

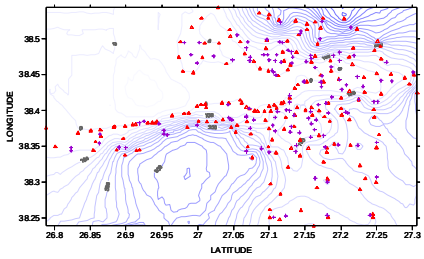
And by this way, geoid undulations were being expressed as depending on geodetic latitude (φ) and geodetic longitude (λ). In the equation, these coordinates of reference points were normalized using

φ° = 38°.4090196, λ° = 27°.1013351

as geometric center of model area.

The model was accomplished using 302 benchmarks in total without any inconsistent point, because during the modeling studies probable inconsistent points have been removed. 181 of these benchmarks were taken as modeling pins, and the rest 121 points were chosen for testing the model.

Case Study : #Continue-2#
İzmir Local Geoid Model



In the figure, it can be seen that the distributions of reference points and test points in the area of study.

For modelling the geoid of the region, geoid heights in the benchmarks were calculated according to equation 11 to use the coefficients of the fifth degree polynomial according to least squares adjustment method.

Case Study : #Continue-3#
İzmir Local Geoid Model

$$N = h_{ITRF96} - H_{Nat.Ver.Datum}$$

In the equation, $H_{Nat.Ver.Dat.}$ is practical height in National Vertical Datum, h_{ITRF96} is ellipsoidal height that is referenced to GRS80 ellipsoid and derived from GPS measurements and N is geoid height of corresponding reference point.

After generating the polynomial as the deterministic part of the computation algorithm, a simple collocation method was applied. The procedure is for computing the signals of both modeling points and test points was applied.

Case Study : #Continue-4#
Testing Model

For testing the created geoid model, 121 test points of which geoid heights had already been known from the GPS and levelling measurements, were used. After collocation method, the root means square error, computed according to real errors (ε), has been found **± 3.9 cm.**

This value also expresses the fitting level of the model to the data. The maximum error was found 10.41 cm. And the number of points whose error is between ±5 cm interval is 18 among the 121 points. It is also seen that the maximum errors were calculated for the exterior points of the model area and this situation is natural .

Conclusion and Recommendations

* The major motivation of this study is to emphasize what a precise geoid model means for routine applications of geodesy and surveying, which are carried out using GPS positioning technique.

* Large scale map production for different purposes, GIS applications, engineering surveys etc. can be said in comprises of these applications. Obtaining physical heights of points from GPS measurements is a very important handicap in application.

Conclusion and Recommendations #Continue-1#

* However, it is implied that to overcome this problem via having a precise geoid model in the region of study is the most advantages solution.

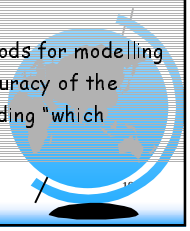
* On the other hand, applying levelling measurements to obtain physical heights of new points in each time instead of deriving them from just GPS measurements is not practical at all.

* Because, as is very well known, levelling measurements needs high cost and long observation time although that provides high accuracy in height.

Conclusion and Recommendations #Continue-2#

* Utilizing a precise geoid model, orthometric heights or practical heights (as in the case study of this paper) are obtained from GPS measurements. Because of that, the studies of geoid modelling have increased its importance after widespread use of GPS technology in Geodetic aims. Also geoid modelling has become indispensable part of geodetic infrastructure studies.

* From this view point, there several methods for modelling the geoid. Available data and required accuracy of the model are two essential criteria while deciding "which method will be used".



Conclusion and Recommendations #Continue-3#

* Investigations were shown that the required accuracy level of the model can be reached by employing geometric approach in local studying area using GPS and Levelling data.

However, to be possible reach higher accuracies with combining more data groups such as gravity, satellite altimetry and geopotantial model in a complete algorithm in regional manner, for practical geodetic works, geometrical solution was found satisfying enough

This is necessary to say that local geoid models with sufficient accuracy are important for the geodetic infrastructure in vertical in Turkey, and will be important at least until national geoid model of Turkey will reach the applicable accuracy level in practical geodetic applications.

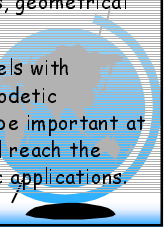


FIG WORKING WEEK 2004

THANK YOU !

e-mails : celikn@itu.edu.tr
bihter@itu.edu.tr

May 24, 2004