A note on contemporary geoid investigations in Bulgaria

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A Note on the Contemporary Geoid Investigations in Bulgaria

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Abstract. Investigations of the geoidal shape in Bulgaria began in the 1960s. Depending on the methods applied, various products are distinguished among the results achieved: astro-gravimetric geoid, geopotential geoid, Doppler geoid, GPS geoid.

Input data for the astro-gravimetric quasi-geoid determination, a part of the 1942/83 reference frame, are the results of astronomical and geodetic measurements in the National first-order control network, the gravity survey of the territory of the country, and terrain elevation data within and outside it. The accuracy achieved is limited by the gravity information available, density of astronomical points and initial data quality.

The shape of the geoid is also determined by means of various geopotential models. Experiments have shown that model resolution worse than $2° \times 2°$ allows to retrieve roughly only the general trend of the geoidal shape in the region.

Based on the Transit satellite Doppler observation results and trigonometric heights of some 25 points of the first-order control, the shape of the Doppler geoid is derived over the territory of the country. Accuracy and density of discrete points contribute to achieve the optimal resolution inherent to this method.

Similar approach is being applied to determine the geoidal shape over the whole national territory or parts of it using GPS data. After having them connected to the national heighting system using spirit levelling, these data will control further geoidal determinations based on astrogeodetic measurements, terrain and gravity data extracted from digital models of relevant resolution.

Investigations on the shape of the geoid in Bulgaria began in the 1960s. Depending on the methods applied, various products can be distinguished, each of them briefly described below.

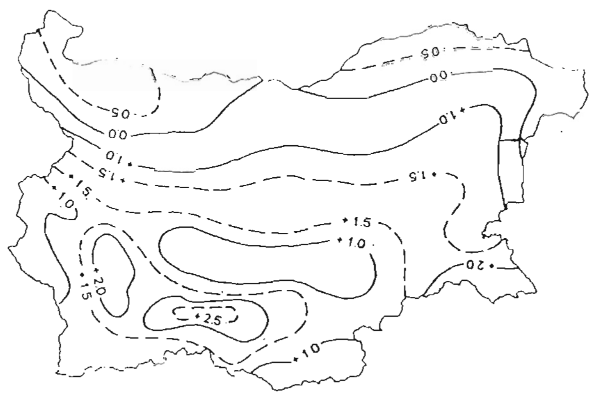

Fig. 1. The astro-gravimetric geoid

The astro-gravimetric geoid

To meet the requirements of the Unified Astro-Geodetic Network of the Central and East European Countries, the shape of the Molodenski quasigeoid has been determined over the territory of Bulgaria [Petrov, 1972]. The astro-gravimetric method has been applied using one fiducial point (near the Danube river coast line) where the height anomaly has been defined within the frames of the UAGN. Some 40 astronomical point (about 55 km mean interstation distance) have been used. Bouguer gravity anomalies have been extracted from a 1:200000 gravity map compiled using gravity data referred to the Potsdam system and normal gravity values computed by the Helmert (1901-1909) formula. The influence of the masses outside the national territory, where no gravity information has been available, was accounted through the attraction of the topographic layer.

Derived in this way, the quasigeoid is graphically presented at figure 1. Contour lines are drawn up at 0.5 m intervals and show relatively the relief of the surface concerned. To become absolute values, the contours must be referred in a proper way to a particular heighting system.

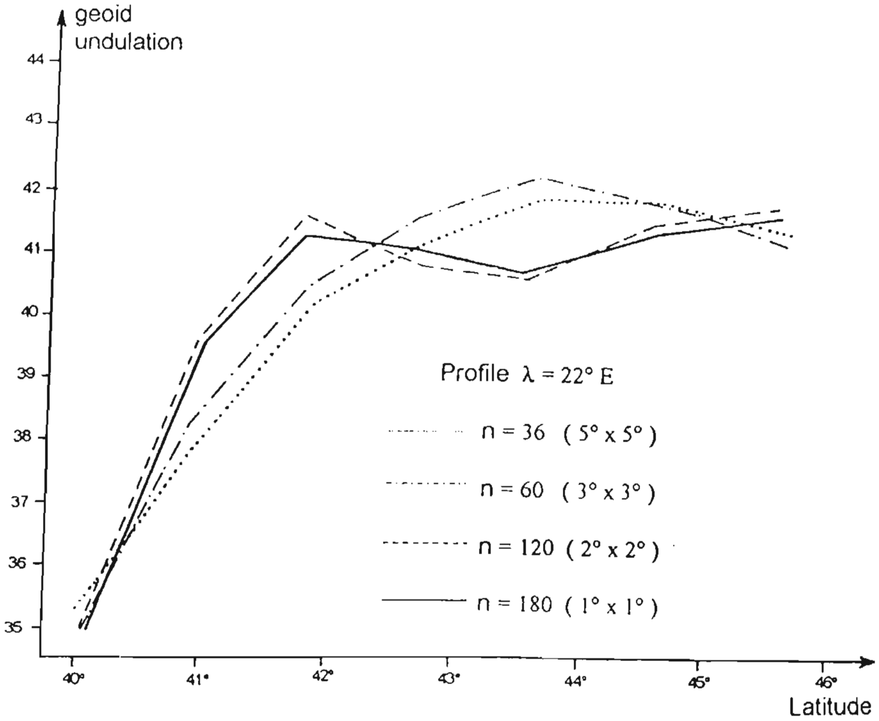

Fig. 3. Geopotential geoid resolution capability

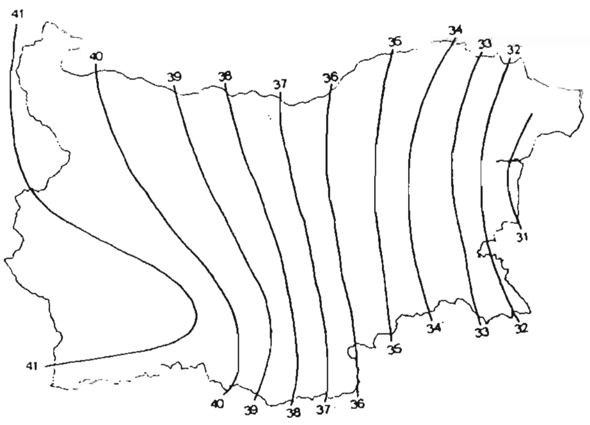

Fig. 2. The GEM10C geopotential geoid

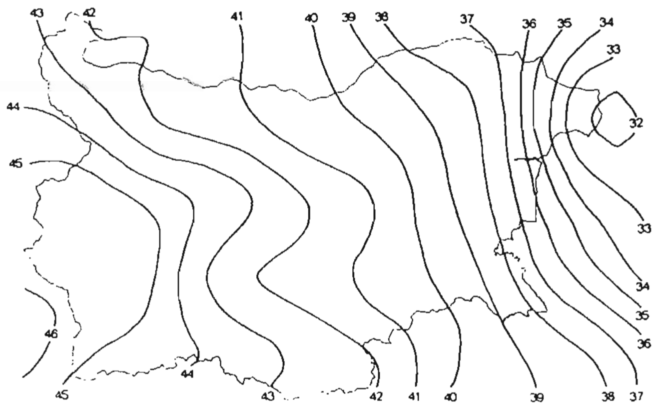

Fig. 4. The OSU91A geopotential geoid

The geopotential geoid

To define the shape of the geoid various geopotential models have been used - GEM10C, OSU91A, etc. Model resolution has been tested along selected profiles which reflect the specific regional terrain features. As expected, models of 2° × 2° cells provide only generalised information, thus retrieving the trend rather than the existing reality. In the westernmost parts of the country, where satellite altimetry data have no influence due to the remoteness of the sea, the GEM10C geoid (fig. 2) profiles do not significantly differ from that of a model of degree and order 120 (fig. 3).

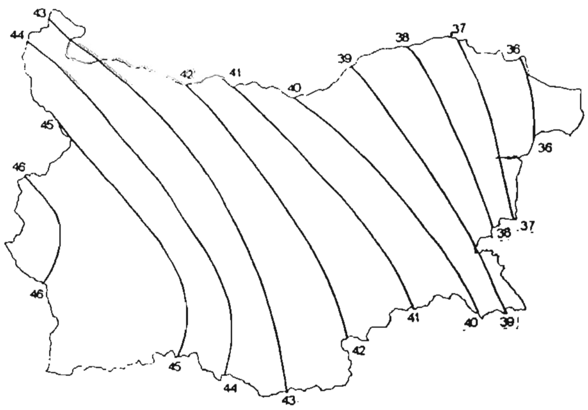

Fig. 5. The Doppler geoid

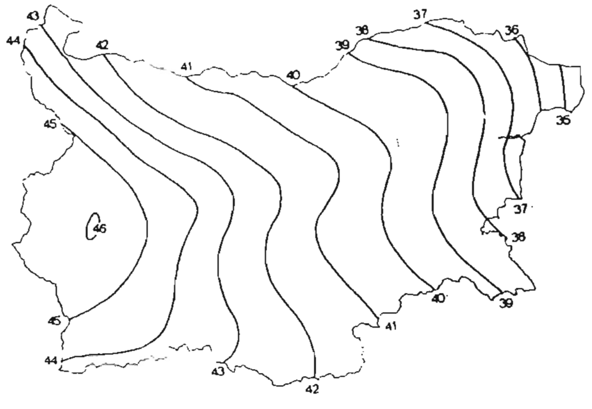

Fig. 6. The GPS geoid

The OSU91A model (fig. 4) shows more optimistic results, featuring, besides the long-wave structure, also some local anomalies which are tested using GPS results further on.

The geopotential geoids are referred to the GRS80 system and, within the resolution of each of them, consistent with the Conventional Terrestrial Reference Frame as realised by the International Earth Rotation Service products. Forthcoming is testing of the EGM96 geopotential model.

The Doppler geoid

The Doppler geoid results from interpolation of the height anomalies of some 25 first-order control points determined with Transit satellite observations. Generally, these points are not connected to the precise spirit levelling network and have trigonometric heights only. Compared to the GPS results obtained later on 14 Doppler points, the ellipsoidal height accuracy estimate amounts 0.53 m. The difference between normal and orthometric heights in Bulgaria is of the same order as the accuracy of the discrete data, and, therefore, the problem to define what is the nature of the resulting surface is not discussed.

The accuracy and density of Doppler points contributes to achieve the optimal resolution of geoidal model of this type. As the Doppler data are defined to the WGS84, the geoid (fig. 5) is referred to this system as well.

The GPS geoid

Connecting Bulgaria to the EUREF and building up the BULREF network have allowed for referencing the GPS measurements in the National Control Network to an advanced terrestrial reference frame, such as ETRF-89 [Altiner et al., 1996]. The increased number of GPS points has gradually allowed for studying the shape of the geoid more in detail. However, the normal heights of the control points are in common trigonometrically determined which does not correspond to the accuracy of GPS heights. Therefore, the results obtained so far (fig. 6) are of preliminary nature only.

Analysis of results

Comparing the geopotential models we see that both GEM10C (fig. 2) and OSU91A (fig. 4) represent the general features specific for the geoid surface in the region, the slope, long-wave structure, etc. Meanwhile, the details are retrieved much better by the OSU91A model.

The different nature of the initial data and reference systems used in the astro-gravimetric geoid (fig. 1) and the other ones do not allow to assess the accuracy achieved. But, analysing carefully the contour lines, one can identify some similarities between the negative structures in the north-western and southern parts of the country, as well as the positive structure in the south-western region, existing both in the astro-gravimetric geoid and the OSU91A model.

Based on the existing GPS results, the accuracy of the OSU91A geopotential model over the territory of the country has been estimated. For this reason a sample of 124 GPS points separated in six clusters was used. At each point two geoidal height values are obtained, one of them using the OSU91A model, and the other computed as a difference between the corresponding GPS and normal heights. The discrepancies of the geoidal heights at each point are analysed by clusters, and, as shown in table 1, the sample statistics vary in a broad range. Extreme values are obtained in the far north-east, where the difference between the geopotential and GPS geoids is more than 2 m (fig. 4, 6). The root mean square value over the whole national territory is 0.79 m.

Similar comparisons are carried out at 9 points of the BULREF network precisely connected to the heighting system using spirit levelling. The root mean square difference obtained equals 0.94 m.

Conclusions

Due to the complexity of the morphology and terrain features in Bulgaria, one cannot expect satisfactory results coming out from geoidal studies based only on geometrical interpolation of height anomalies (geoid undulations) of discrete points, no matter how dense they are. High resolution digital models of terrain elevation and the gravity field of the country, which are already available, will be included in the forthcoming investigations. Referred to the GRS80 system and supplemented with the global geopotential model data needed to account for the influence of the remote zones, these data, along with some new astronomical points, would allow to identify

Table 1. OSU91A and GPS geoid intercomparison

Cluster	Number of points	OSU91A-GPS difference [m]	
		Average	RMS
NW	34	-0.03	0.50
N	12	0.11	0.25
NE	60	-0.39	1.04
SE	3	0.01	0.53
S	12	0.14	0.24
SW	3	-0.17	0.94
Total	124	-0.17	0.79

the detailed structure of the geoid and to optimise implementation of the astro-gravimetric method. The EUREF, BULREF, EUVN and National Control Network points will be used to control the results achieved in this way.

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