Geoid Model for Surveying in Latvia

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SUMMARY

In our country, we have different local and global geoid models available for use with GPS/GNSS receivers. Common purpose of all used models is to provide accurate and fast recalculation of ellipsoidal heights obtained by contemporary GPS/GNSS to heights over the Baltic Sea level, but every model will always have its own different accuracy. Differences of heights between fitted local geoid models can reach up to 10 cm, but differences between unfitted global and local geoid models could reach up to one meter level.

In Latvia, geoid model LV'98 is broadly used and it follows from this that we shall use the advantages of this one specific model as one common height reference surface. And if other height reference equipotential surfaces – geoid or quasigeoid – are used, expression or formula for recalculation shall be given with reference to LV'98 as base model.

For the evaluation of conformity of different models and reference equipotential surfaces for recalculation of height, global Earth Gravitational Model EGM08 is used as reference surface. It includes also results of recent satellite mission data over Baltic region. In order to solve continuity problems on state border and to make evaluation process more reliable it is necessary to have good cooperation with all neighborhood countries, especially Estonia and Lithuania.

Results of present study enable mutual transformation of heights surveyed in different systems, which are determined by use of different geoid (GPS geoid) models. That enables compatibility of heights over sea level surveyed in the result of contemporary GPS/GNSS within limits of fixed accuracy, including compatibility of measurements performed more than ten years ago with results of this day measurements. In order to use geospatial data in public data bases successfully for territorial planning, civil engineering, cadastre, mapping and other GIS applications, it is vitally important to have joint geodetic reference system, as well as compatibility of height component.

Practical geodetic works and researches are performed in Latvia in order to improve the accuracy of the used models, as well as to ensure general compatibility of geospatial data of various periods.

KOPSAVILKUMS

Mūsu valstī ir pieejami vairāki lokālie un globālie ģeoīda modeļi darbam ar GPS/GNSS uztvērējiem. Šo visu lietojamo modeļu kopējais mērķis ir nodrošināt precīzu un ātru ar modernām GPS/GNSS iegūto elipsoidālo augstumu pārrēķināšanu uz augstumiem virs Baltijas jūras līmeni, bet katram modelim vienmēr būs sava atšķirīga precizitāte. Starpības augstumiem starp valsts augstuma tīklam piesaistītiem ģeoīda modeļiem var sasniegt līdz pat

10 cm, bet starpības starp augstumiem nepiesaistītu globālo un lokālo modeļu pielietojuma gadījumos var sasniegt pat viena metra robežu.
Latvijā ļoti plaši tiek lietots ģeoīda modelis LV'98, tamdēļ mums ir jāizmanto šī viena konkrētā modeļa priekšrocības, ko tas sniedz kā kopēja augstuma atskaites virsma. Un ja tiek lietotas citas augstuma atskaites līmeņvirsmas – ģeoīda vai kvazi-ģeoīda modeļi, tad jāsniedz pārrēķina izteiksme jeb formula, atsaucoties uz LV'98 kā izejas jeb bāzes modeli.
Lai izvērtētu dažādu modeļu un atskaites līmeņvirsmu atbilstību augstuma pārrēķināšanai, tad kā atskaites virsma ir lietots Zemes gravitācijas lauka modelis EGM08. Tas satur arī jaunāko gravimetrisko Zemes mākslīgo pavadoņu mērījumu rezultātus Baltijas reģionam. Lai nodrošinātu modeļa nepārtrauktību uz valstu robežām un tā novērtēšanas process būtu pilnīgāks, tad būtiska ir teicama sadarbība ar kaimiņvalstīm, jo īpaši Igauniju un Lietuvu.
Šī izpētes darba rezultātā tiek nodrošināta savstarpēja pārrēķināšanas iespēja starp dažādās sistēmās uzmērītiem augstumiem, kas tikuši noteikti lietojot atšķirīgus ģeoīda (GPS-ģeoīda) modeļus. Tas nodrošina modernu GPS/GNSS metožu rezultātā uzmērīto jūras līmeņa augstumu saderību noteiktas precizitātes robežās, t.sk. vairāk kā desmit gadu senu mērījumu saderību ar šā laika mērījumu rezultātiem. Lai ģeotelpiskos datus no publiskām datu bāzēs varētu vienlīdz sekmīgi lietot teritorijas plānošanā, būvniecībā, nekustamā īpašuma kadastrā, kartogrāfijā un dažādos GIS pielietojumos, tad vitāli svarīga ir definētā ģeodēziskā atskaites sistēma, kā arī jau daudzkārt minētā augstuma komponentes saderība.
Latvijā praktiskie ģeodēziskie darbi un pētījumi tiek veikti, lai paaugstinātu lietoto modeļu precizitāti, kā arī nodrošinātu dažādu laika periodu ģeotelpisko datu vispārējo saderību.

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1. INTRODUCTION

In our country, we have different local and global geoid models available for use with GPS/GNSS receivers. Common purpose of their use is for height determination in relation to the Baltic Sea level, but the accuracy achieved is sometimes different. Differences between fitted local geoid models can reach up to 10 cm, but differences between unfitted global and local geoid models could reach up to one meter level.
Since 1998 in Latvia, geoid model LV'98 is used for recalculation of heights of points from ellipsoidal heights to heights above sea level in most wide extent and for the longest period. Above-mentioned model was implemented after the successful completion of joint Danish–Baltic sector programme in geodesy. Research of geodetic network and joint development and implementation of height reference geoid model took place simultaneously in all three Baltic countries – Latvia, Lithuania and Estonia.
For the evaluation of conformity of different models and reference equipotential surfaces for recalculation of height, global Earth Gravitational Model EGM08 is used as reference surface (Ellmann et al., 2009). It includes also results of recent satellite mission data over Baltic region.
Further improvement of accuracy of geoid model is possible after the obtaining of results of repeated levelling and linking thereof with GPS/GNSS network (Jivall et al., 2008), in order to get coverage of geodetic points of higher accuracy and more dense distribution. Now we are working actively with these works in Latvia, we are expecting also that new global geopotential models will be available. In the result of comparison and analysis of these global models and of local gravimetric data, all stakeholders, i.e., both local national responsible services and developers of global models gain some benefit.

2. MODELLING AREA

Calculations of Latvian geoid are carried out most often in modelling area adopted by Nordic Geodetic Commission (NKG) (Forsberg et al., 1997), where also territories of Latvia and other Baltic countries are included, as shown in Fig. 1.

Fig.1 Modelling area of Latvian geoid

During modelling tests, optimal areas for geoid calculation were analyzed. In Latvia, area from 55 degrees up to 59 degrees of Northern latitude and from 20 degrees up to 30 degrees of Eastern longitude (i.e. 32361 calculation points, root mean square of anomaly 16,44 mGal) is mainly used. The area of such domain is 270 thousands square kilometers. As new and more accurate gravimetric data, which have been became available over Baltic Sea, are evaluated, calculation area for territory of Latvia could be increased. The typical modeling area for NKG geoid is the largest marked area, but boundaries of local area are depicted in the right bottom corner of Fig. 1. When modelling area is increased, errors that arise in the vicinity of outer boundary of modelling area are reduced, i.e. „edge effect" is eliminated. Beyond territory of modelling area, working boundaries shall be increased by more than 100 km. Condition that accurate and verified gravimetric data shall be available throughout the modelling territory shall be met (Tscherning et al, 1992).

3. GEOID MODELS

The first digital geoid model for the territory of Latvia was created in 1993 in Helsinki. Calculation were performed in Finnish Geodetic Institute, whereby experience accumulated by Nordic Geodetic Commission and initial information that consists of results of gravimetric research, digital characteristics of terrain and of coordinates of levelling points that are determined by GPS measurements, and of heights thereof was used. Based on the last data, the computed gravimetric geoid is linked with height system approved in the country (Kūkums, 1993).

The further digital geoid models were calculated in Copenhagen in 1996 and later by use of larger stocks of initial data and new geopotential models (Pavlis et al., 1997). While research was performed, some local model errors were detected by use more abundant and more accurate initial data. Therefore there is need for densifying of network of precise levelling points coordinated with GPS/GNSS measurements, i.e. to carry out integration of above-mentioned geodetic networks and to perform new gravimetric measurements (Kaminskis and Forsberg, 1997).

While digital geoid models were studied, places were detected, where normal heights were erroneous and ellipsoidal heights were inaccurate. Points, which were characterized by the

greatest errors of initial data, were detected and they were omitted in the further calculation stage of the model. Such errors are detected, if during the comparison process large differences between heights determined by levelling and heights calculated according to created digital geoid model are obtained. However, places with lesser initial data errors are used for further analysis. Triangulation points included in national GPS network, heights of which are determined by levelling of fourth order, also were used. Most often the cause of formation of erroneous height of the origin point is changed height of levelling mark. Many pre-war benchmarks that are set in concrete or stone posts have experienced changes of height.
The initial information required for transformation of digital model of gravimetric geoid to height system adopted in Latvia was comprised by heights of 131 levelling points situated within territories of Latvia, Lithuania and Estonia and by three-dimensional coordinates of the same points determined by GPS/GNSS measurements.
Gravimetric geoid is transformed to the adopted height system by several iterations, points collocated by the linkage, where difference between the ellipsoidal and levelled height compared with heights of geoid models is the greatest, were excluded after each cycle. The heights calculated according to transformed geoid model will already include the errors of collocated points. They will be then residuals, therefore detailed research of collocated points is necessary. When transformation is completed, the best fitting linkage points are selected.

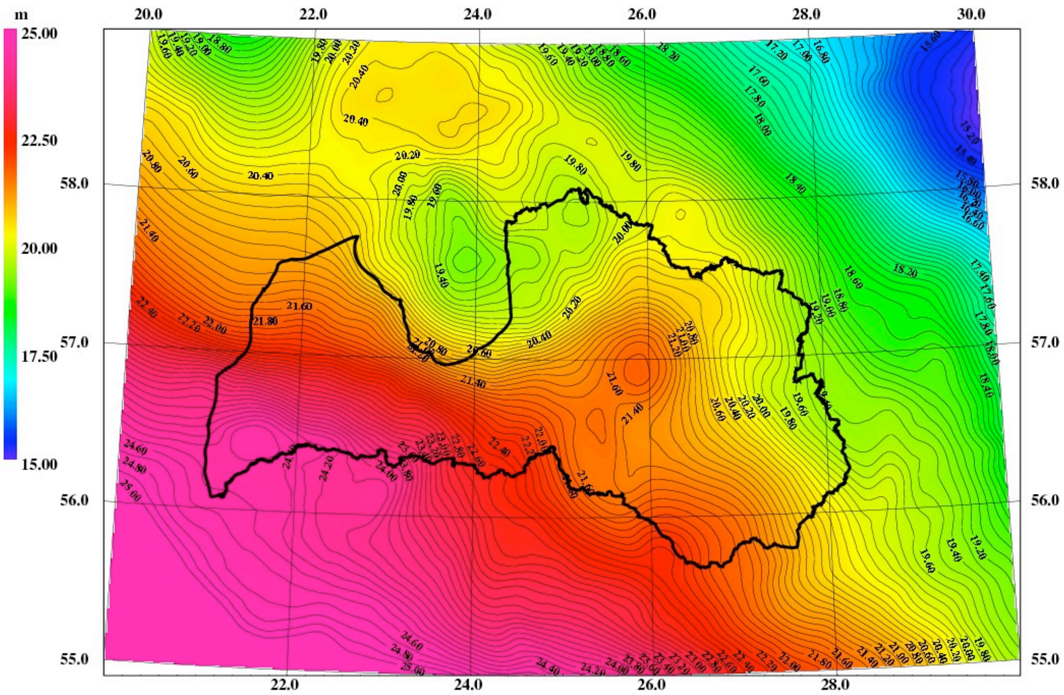

Fig.2 Heights of geoid LV'98 calculated in 1998 above GRS 80 ellipsoid

Geoid heights vary in the territory of Latvia from 24,5 m in Liepaja district at the Baltic Sea down to 19,3 m in Balvi district at the border with Russia, Fig. 2. The mean gradient of change of geoid height in the direction of line connecting the above-mentioned places reaches maximally 20 mm/km. This gradient will be smaller in all other directions.

Characteristic of accuracy of digital geoid model covering the territory of the state and calculated in 1998 is created by use of combined results of determination of coordinates and levelling of points of national GPS networks (Kaminskis and Forsberg, 1997). The root mean square error of this model will not exceed 6 cm anywhere in the territory of the country.

4. CONCLUSIONS

In order to do not make the accuracy reached by the gravimetric geoid worse, when it is transformed to the adopted national height system, network of sufficiently dense and accurate linkage points, the normal heights and ellipsoidal heights of which would be determined with accuracy that is not smaller than accuracy of the forecasted geoid model, is required. However, there is it absolutely unreal to determine normal heights of linkage points with accuracy of several centimetres on the basis of the present national levelling network. Therefore it will be possible to create digital geoid model of the territory of Latvia of the next level according to accuracy only after the completion of gravimetric measurements and of national vertical geodetic network. Such method for calculation of heights of survey points based on the determination of ellipsoidal and geoid heights is very perspective nowadays. In order to use the data in common data base for territorial planning, civil engineering, cadastre, mapping and other GIS applications, it is important to have joint geodetic reference, as well accurate height component.
Practical geodetic works and researches are performed in Latvia in order to improve the accuracy of the used models, as well as to ensure general compatibility of geospatial data of various periods.

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BIOGRAPHICAL NOTES

M Sc.ing.(1995). Author of more than 10 scientific papers. Participated in 3 NKG Summer schools for researchers in geodesy and many international conferences. Training at the Finnish Geodetic Institute in 1994, National Survey and Cadastre (KMS) and Copenhagen University in 1995/1996.
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