

EUROPEAN VERTICAL REFERENCE SYSTEM IN BALTIC COUNTRIES

Armands Celms, Inese Bimane, Ilona Reke
Latvia University of Agriculture

Abstract

At the moment all three Baltic countries – Estonia, Latvia and Lithuania – use Baltic Normal Height System 1977 as a national height system. But the European Union regulations declared the European Vertical Reference System as a national height system. For height transformation there is a transformation formula for each European country. After calculations it is seen that height difference between Baltic Normal Height System 1977 and the European Vertical Reference System depends on point location in the territory (coordinates). This unequal height difference between both height systems will cause unequal height values on border connection points between the Baltic countries.

Key words: European Vertical Reference System, transformation formula, border connection points.

Introduction

Levelling network is a national height system forming element. Levelling network ensures the realization of various functions in the national economy. Using Class I leveling results for any kind of transformations, it is necessary to know the accuracy of established levelling network (Celms et al., 2013). At the moment all three Baltic countries – Estonia, Latvia and Lithuania – use Baltic Normal Height System 1977 as a national height system. In Latvia it is determined by the Cabinet of Ministers. But the community of surveyors and land managers consider that the existing height data are out of date; vertical movements need a new height system. The Latvia Geospatial Information Agency determined that from the 1st of August, 2014 Latvia will use the European Vertical Reference System as a national height system. The use of the European Vertical Reference System in each European Union member state is determined under Directive 2007/2/EC of the European Parliament and of the Council as of 14 March 2007, establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). (Directive 2007/2/EC of ..., [b.g.]

Methodology of research and materials

The Federal Agency for Cartography and Geodesy of Germany and Reference Frame Sub-Commission for Europe have developed a transformation formula for each European country for the purpose of height transformation from existing Baltic Normal Height System 1977 to the European Vertical Height System:

$$H_{(II)} = H_{(I)} + a_1 + a_2 \times M_0 \times (LAT - LAT_0) + a_3 \times N_0 \times (LON - LON_0) \times \cos(LAT) \quad (1)$$

Where: $H_{(I)}$: height in the source system [m];

$H_{(II)}$: height in the target system [m];

M_0 : radius of curvature in the meridian of GRS80 [m] in P_0 ;

N_0 : radius of curvature perpendicular to the meridian of GRS80 [m] in P_0 ;

LAT: latitude in ETRS89 [radian];

LON: longitude in ETRS89 [radian];

$P_0(LAT_0, LON_0)$: Reference point of the transformation;

a_1 ...vertical translation [m];

a_2 ...slope in the direction of the meridian [radian];

a_3 ...slope in the direction perpendicular to the meridian [radian] (Description of national..., [b.g.]).

Values of transformation formula for Latvia are:

- $M_0 = 63840416.7$ m;
- $N_0 = 6393195.1$ m;
- $LAT_0 = 56^\circ 58' = 0.99426$ radian;
- $LON_0 = 24^\circ 53' = 0.43430$ radian;
- $a_1 = 0.15374$ m;
- $a_2 = 0.01558$ sec
- $a_3 = 0.01174$ sec (Valsts augstumu izejas ..., 2009).

The transformation formula defines a transformation point in every country. The transformation point in Latvia is not the same as the geographical centre or the centre of gravity of Latvia as it is shown in Figure 1.



Fig. 1. Transformation point, the geographical centre and the centre of gravity of Latvia.

The geographical centre is a point between extreme North – South and West – East points. In Latvia the coordinates of geographical centre are $56^\circ 52' 48.5''$ North $24^\circ 36' 22.4$ East, but the coordinates of the centre of gravity – $56^\circ 52' 51.2''$ North and $24^\circ 59' 01.9''$ East.

According to the transformation formula the height difference between Baltic Normal Height System 1977 and the European Vertical Reference System depends on transformation point location is not equal but depends on transformation point location in the country and the distance to a transformation point. All other values of transformation formula are constant.

To determine the height difference between both height systems for each point in the territory, the following equation is obtained from the transformation formula:

$$H_{(II)} = H_{(I)} + a_1 + a_2 \times M_0 \times (LAT - LAT_0) + a_3 \times N_0 \times (LON - LON_0) \times \cos(LAT) \quad (2)$$

$$H_{(II)} - H_{(I)} = 0.15374 + 0.01558 \times 63840416.7 \times (LAT - 0.99426) + 0.01174 \times 6393195.1 \times (LON - 0.43430) \times \cos(LAT) \quad (3)$$

Assuming the height difference $H_{(II)} - H_{(I)}$ as a constant value gets the curve – the point set with the same height difference. Fig. 2 and Fig. 3 show the curve if $H_{(II)} - H_{(I)} = a_1 = 0.15374$ m.

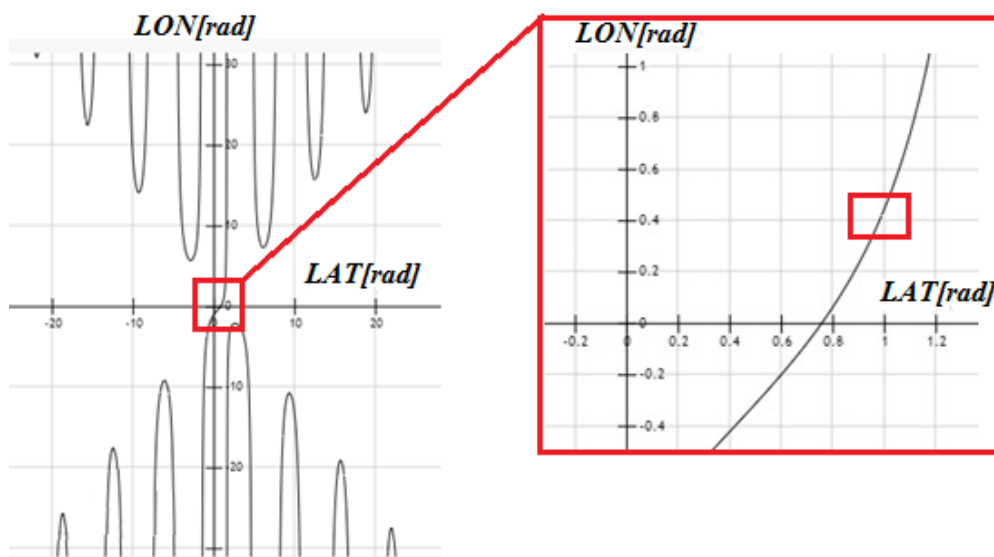


Fig. 2. Curve of the transformation formula if $H_{(II)} - H_{(I)} = a_1 = 0.15374$ m.

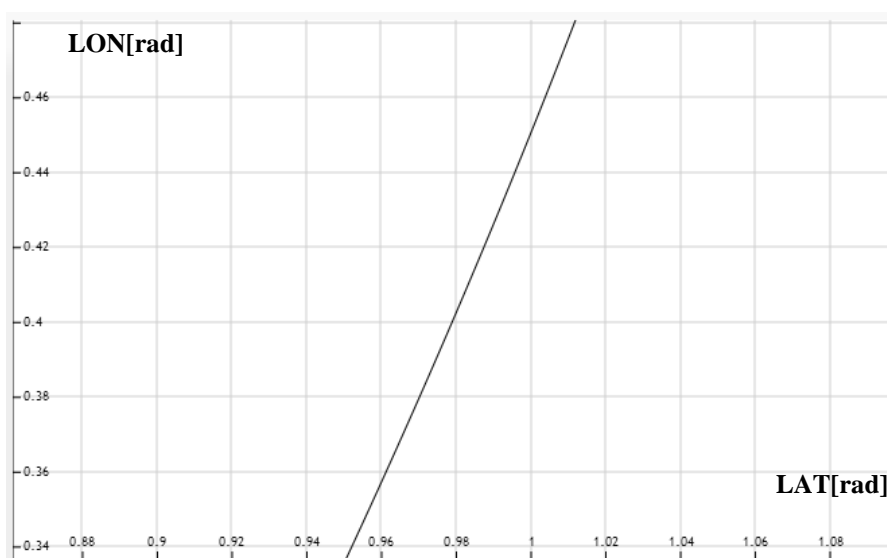


Fig. 3. Part of the curve of the transformation formula if $H_{(II)} - H_{(I)} = a_1 = 0.15374$ m for geographical coordinates appropriate for territory of Latvia.

According to transformation formula calculations in Latvia the difference between Baltic Normal Height System 1977 and the European Vertical Reference System will be 135 mm in the south-eastern part of Latvia and will increase to 169 mm in the north-western part (see Fig. 4). This could make an additional error for height determination between points.

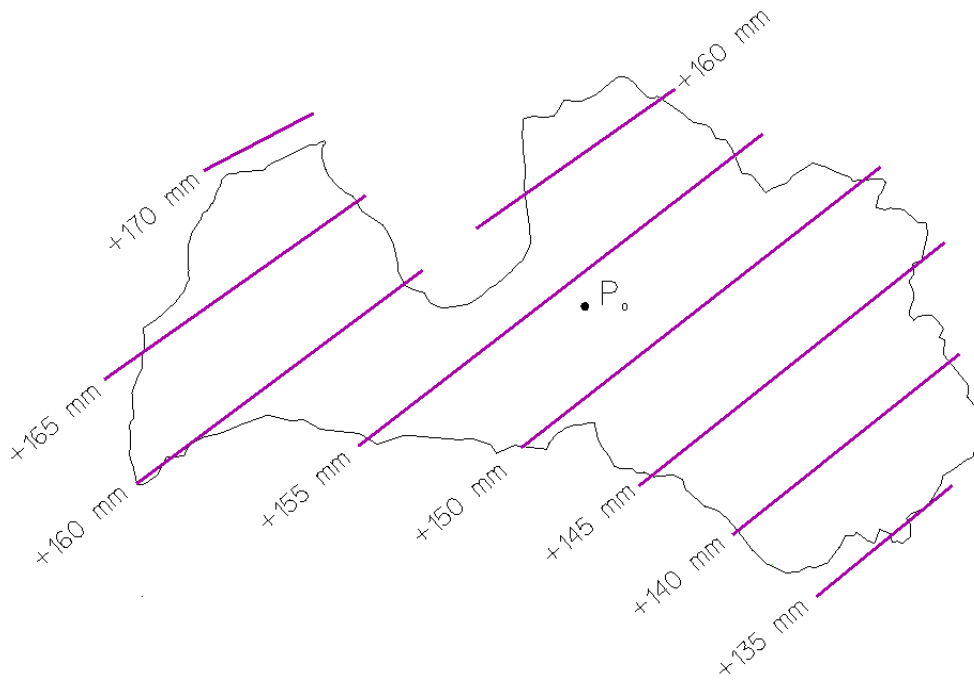


Fig. 4. The difference between height systems in Latvia and transformation point P_0 .

Discussions and results

Figure 5 shows the difference between both height systems in millimetres and the location of the transformation point in all three Baltic countries.

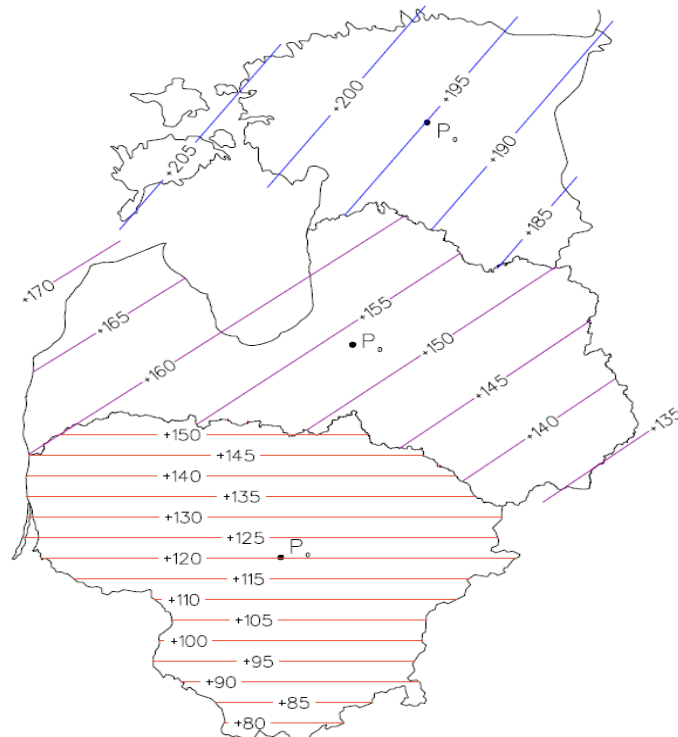


Fig. 5. The difference between height systems and transformation point P_0 in Baltic countries.

Fig. 5 shows that in Lithuania the difference between height systems will be from 80 mm in the south part until 150 mm in the north part of the country. In Estonia – from 185 mm in the south-east part until 207 mm in the north-west part of the country. The European Vertical Reference System will cause unequal height values at the connection points on the border: the height difference of same point in Latvian and Estonian or Latvian and Lithuanian height system will be until 33 mm on the state border (Fig. 6.).

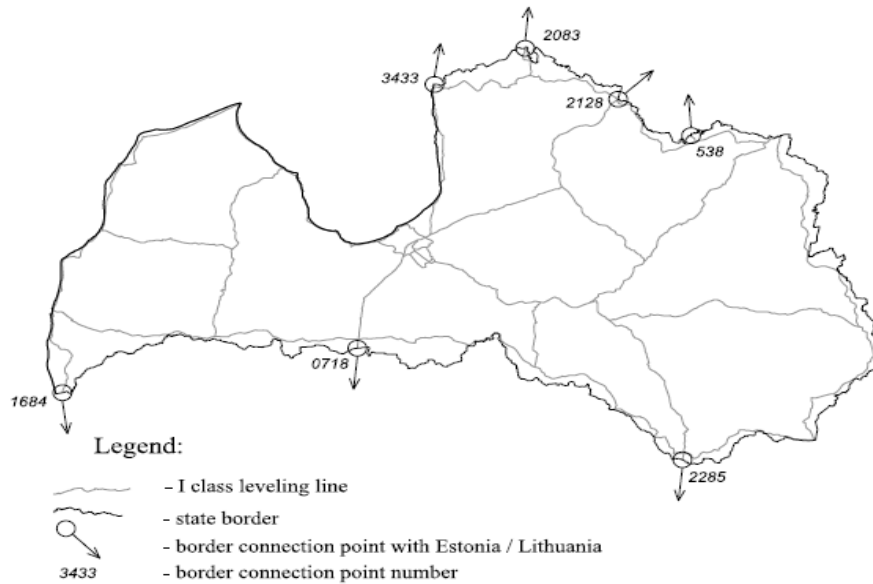


Fig. 6. Border connection points with Estonia and Lithuania.

Table 1 shows the height difference in the border connection points. On the border of Latvia – Estonia the height difference in the European Vertical Reference system in both countries will be 32 to 33.9 millimetres, but on the border of Latvia – Lithuania the connection point heights in Latvia and Lithuania in the European Vertical Reference System will be -0.5 mm to 19.6 mm. So the same point height on the border will be different in each country in the European Vertical Reference System. There will be no more height connection between the Baltic countries.

Table 1

Height difference in border connection points

	Point No.	Point height, m (BAS77)	Height difference between BAS77 and EVRS in Latvia, m	Height difference between BAS77 and EVRS in Estonia/Lithuania, m	Difference between heights of EVRS in Latvia and Estonia/Lithuania, mm
LV-EE	3433	3.21	0.163	0.197	-33.9
	2083	72.37	0.162	0.194	-32.0
	2128	50.93	0.157	0.190	-33.3
	538	78.64	0.153	0.186	-33.4
LV-LT	1684	11.01	0.160	0.140	19.6
	718	96.4	0.160	0.160	-0.5
	2285	138.9	0.137	0.130	7.4

Figure 7 and Figure 8 show the height differences after using the European Vertical Reference System along the whole borderline Latvia – Estonia and Latvia – Lithuania. As it is seen in Figure 7, direction of height difference between Baltic Normal Height System 1977 and the European Vertical Reference System has an equal increase in Latvia and Estonia: from south-east to north-west of the country. Therefore the height difference between both countries using the European Vertical Height System along the whole borderline is equal –33 millimetres on average (Fig.7).

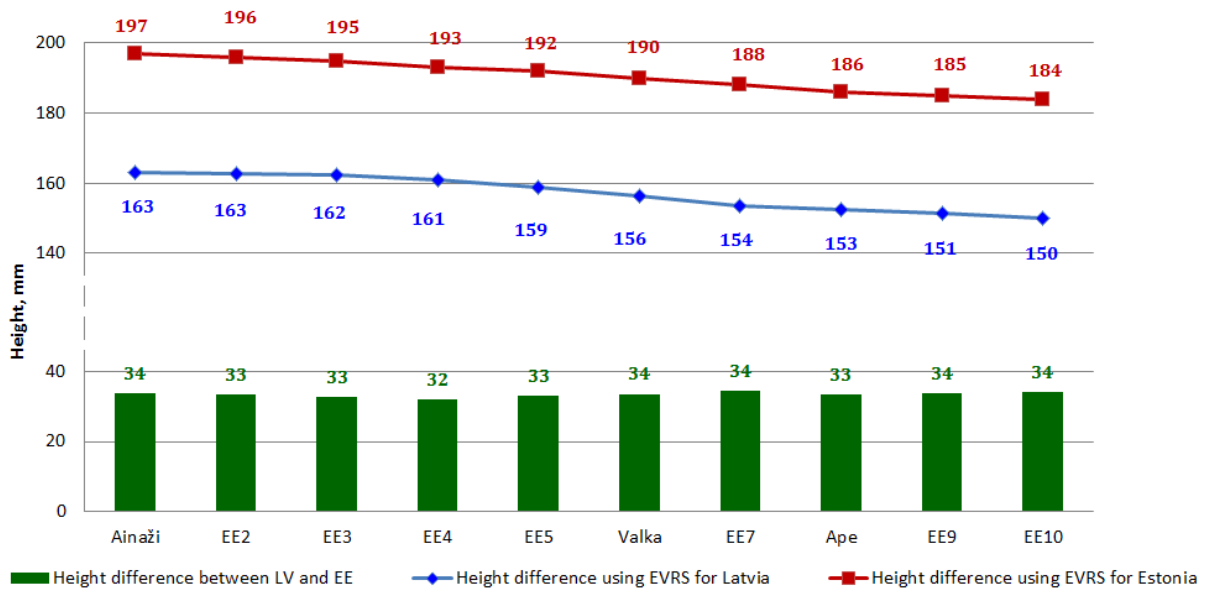


Fig. 7. Height difference between Baltic Normal Height System 1977 and European Vertical Reference System on border line Latvia – Estonia.

But the direction of height difference between Baltic Normal Height System 1977 and the European Vertical Reference System does not have an equal increase in Latvia and Lithuania. In Latvia it increases from south-east to north-west of the country but in Lithuania – from south to north of the country. Therefore the height difference between both countries using the European Vertical Height System along the whole borderline is different: 20 to -5 millimetres (Fig.8). There are 2 points on the borderline with the same height in Latvia and Lithuania using the European Vertical Reference System.

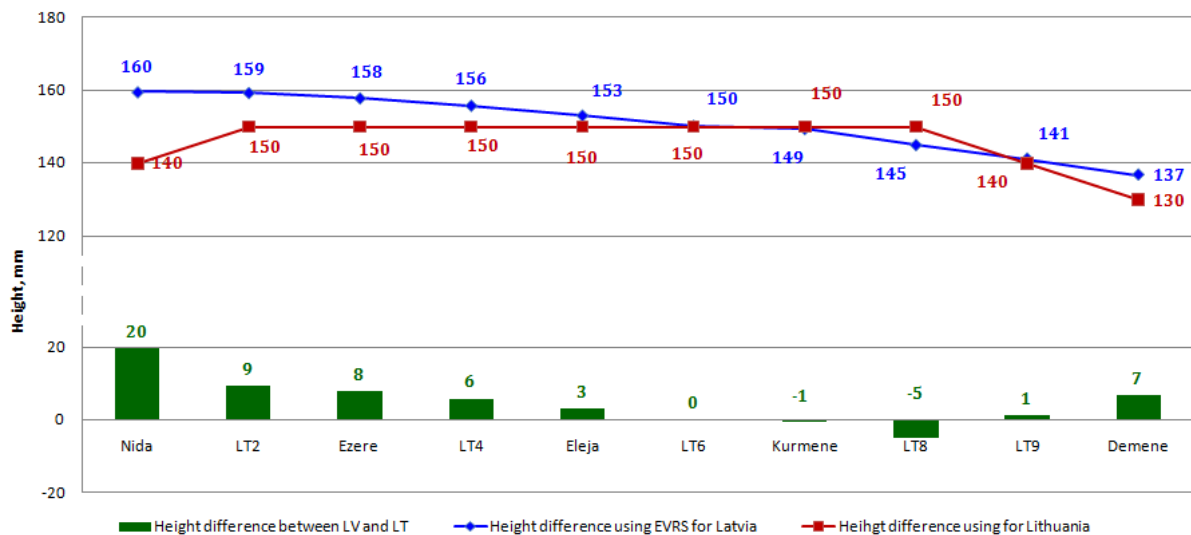


Fig. 8. Height difference between Baltic Normal Height System 1977 and European Vertical Reference System on border line Latvia – Lithuania.

The height transformation to the European Vertical Reference System will cause many changes and it is necessary to study and evaluate the system before using it.

Conclusions and proposals

1. The differences between Latvian - Estonian and Latvian - Lithuanian planned EVRS height systems is in the range from -33.9 to +16.9 mm.
2. United EVRS height system for the common Baltic space is advisable.

3. The existing height system transformation to the European Vertical Reference System in the Baltic countries will reject the possibility of the direct comparison of the Earth's vertical movement dynamics and comparison of the prior levelling results.
4. It is desirable to give height values for each current geodetic sign in Baltic Normal Height System 1977 after the implementation of the EVRS height system.

References

1. Celms A., Kronbergs M., Cintina V., Baumanė V. (2013) Precision of Latvia Leveling Network nodal point Height. In: Civil Engineering'13: Proceeding of 4th International Scientific Conference, Part I, Volume 4, Jelgava, LLU, p.310.-317. ISSN 2255-7776
2. Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) Viewed 26 February, 2014 (<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:en:PDF>)
3. Description of national Coordinate Reference Systems of European Countries. Viewed 26 February, 2014 (http://www.crs-geo.eu/nr_159882/crseu/EN/CRS_Description/crs-national_node.html?_nnn=true)
4. Valsts augstumu izejas līmeņa noteikšana (2009) RTU Ģeomātikas katedra, Zinātniski pētnieciskais projekts, 63 p.

Information about authors

Armands Celms, Mg.sc.ing., lector, Latvia University of Agriculture, Faculty of Rural Engineering, Department of Land Management and Geodesy. 19 Akademijas Street, Jelgava, Latvia, LV-3001, +37163024618, armands.celms@llu.lv Fields of interest – precise levelling, vertical movements of the Earth's crust.

Inese Bimane, Dr.paed., assistant professor, Latvia University of Agriculture, Faculty of Rural Engineering, Department of Land Management and Geodesy. 19 Akademijas Street, Jelgava, Latvia, LV-3001, +37163024618, inese.bimane@llu.lv Fields of interest – precise levelling.

Iļona Reke, Bc.sc.ing., Master student, Latvia University of Agriculture, Faculty of Rural Engineering, Department of Land Management and Geodesy.