

Federal Agency for Cartography and Geodesy

The European height reference system and its realizations

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Contents

1. UELN-forerunner - Steps of development

- 2. Development of UELN from 1994 to 2007
- 3. EVRS and its realization
- 4. News since EVRF2007
- 5. Related projects
- 6. Future next steps



History of the unification of the European leveling (1864-1890)

- Resolution of 1. General conference of Central European Triangulation in Berlin 1864: comparison of the European sea levels by leveling and establishing of a European datum point
- After 25 years of levelling:
 - Comparison of the European sea levels by adjustment of 48 leveling loops including measurements to 42 tide gauges and analysis of tide gauge observations
 - Computation of normal-orthometric reduction
 - Error of 1km levelling 4-5 mm
 - Helmert: accuracy isn't sufficient for comparison
 - Difference between tide gauges Amsterdam Genoa: -32cm
 - No agreement about datum point

History of the unification of the European leveling (1954-1963)

- 1948 suggestion of Kukkamäki to connect the national leveling networks in Europe
- 1954 Resolution of IUGG in Rom: establishing of a commission for the "United European Leveling Network (UELN)=Réseau Européen Unifié de Nivellement (REUN)"
 - Wide meshed network
 - Adjustment of geopotential differences
 - Separate computation of Northern block because of postglacial rebound
- 1963 final report; temporary end of all activities



History of the unification of the European leveling (1971-1986)

New leveling data in most of the countries both of Western and Eastern Europe

- 1971: General Assembly IUGG in Moscow Reactivation of the IAG Sub-commission UELN
- 1973: first meeting of the IAG Sub-commission UELN in Brussels – work schedule
- 2 computing centers (Delft, Munich)
- 1981 preliminary adjustment without Northern countries
- 1982 separate adjustment of Northern countries with reduction to epoch 1960
- 1986 final adjustment: UELN-73/86

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Extent of UELN-73/86



14 countries 774 nodal points 1083 lines

Activities in Eastern Europe before 1990

- Extension of UELN to Eastern Europe had been a goal since the 1950^s but had not been achieved until the 1990^s.
- Instead:
 - 1957: adjustment of a Uniform Precise Leveling Network (EPNN) of Eastern Europe: datum point Kronstadt, networks 1.O.
 - 1974-1978: Re-leveling of Uniform Precise Leveling Network (EPNN) of Eastern Europe
 - Common measurement epochs
 - Adjustment in Moscow
 - 1973:Map of the Recent Vertical Crustal Movements of Eastern Europe



Contents

- 1. UELN-forerunner Steps of development
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- 4. News since EVRF2007
- 5. Related projects
- 6. Future next steps



UELN-95

- 1993: request of CERCO to establish a Unified Vertical Datum for Europe at the one decimetre level
- 1994: resolution of EUREF symposium in Warsaw
- start with observations from UELN-73/86
- Step by step:
 - Extension to the East
 - Substitution of old data by current 1.order measurements
- Data and computation centre: BKG
- NAP, geopotential numbers/ normal heights, full networks 1.0
- 1999: Handing over of results as <u>UELN-95/98</u>
- 2000: First Definition of EVRS (EVRS2000) with extended UELN-95/98 as basis for realization <u>EVRF2000</u>



Extent of UELN-95/98



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Realization of EVRS2000



- EVRF2000: new adjustment of UELN-95/98 with extension of the network to Estonia, Latvia, Lithuania and Romania
- Results have never been distributed



Contents

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- 5. Related projects
- 6. Future next steps



Request for a new EVRF

9th EC GI-GIS conference June 24-26 2003, La Coruňa:

 Need for harmonization of vertical reference of spatial coordinates

Workshop (EC, EuroGeographics) April 5-7 2004, Frankfurt: "Vertical Reference Systems for Europe"

- Consideration of user requirements:
 - Realization of an up-to-date European height reference frame
 - Continuation of the previous development of EVRS
 - Guarantee of a 1 cm accuracy level for datum and network realization
 - Alignment to IVRS/WHS

Development of the network after 2000

New data of 10 countries after 2000:

Switzerland (2002) Bulgaria (2003) Netherlands (2005) Finland (2005) Norway (2005) Sweden (2005) Slovakia (2007) Lithuania (2007) Poland (2007) Portugal (2007)

update extension update update update update update update update update





Extent of UELN in 2007



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Definition of the European Vertical Reference System and related realizations (frames)

System	EVRS(2000)	EVRS2007		
description	Gravity related height reference system	+kinematical		
datum	W ₀ =U ₀	W ₀ =W _{0E} =const., level NAP		
scale	SI- meter, second	SI – meter, second, TCG time		
Kind of heights	Geopotential numbers: $-\Delta W_P = c_P = W_{0E} - W_P$ normal heights equivalent (specification of reference gravity field provided)			
Tidal system	Zero tide			
Realization	EVRF2000	EVRF2007		
datum	1 point: 000A2530 in the Netherlands with the same geop. number as in UELN-73/86	<u>13 datum points</u> with their geopotential numbers of UELN-95/98		
scale	rod scale and temperature correction, in the authority of the particular countries			
reference gravity field	normal gravity field of GRS80			
adjustment	free			
network	UELN-95/98+ EE, LV, LT, RO (status 2000)	UELN status 2007		
tidal system	No reductions applied: mean tide	Zero tide		
Reduction to a common epoch	FI, NO, SE reduced to 1960	FI, NO, SE, DK, PL, EE, LT, LV, parts of DE, PL reduced to 2000		



Datum points of EVRF2007





EVRF2007



- 27 countries
- 13 datum points
- 7939 nodal points
- 10347 lines
- s₀ = 1.11 kgal·mm
- Adopted 2008 in Brussels

Reduction to zero tide

EVRF2000:

- EVRS defined as zero tidal system
- no reductions were applied in practice mean tidal system
 EVRF2007
- Reduction of the geopotential differences by $\Delta C_z = \Delta C_M - 0.28841 \cdot (\sin^2 \varphi_2 - \sin^2 \varphi_1) - 0.00195(\sin^4 \varphi_2 - \sin^4 \varphi_1)$ in kgal-m

Reduction of the datum points to zero tide

• Formula for reduction of geopotential number to zero tide:

 $C_{dp2007} = C_{dp95/98} - 0.28841 \cdot \sin^2 \varphi - 0.00195 \cdot \sin^4 \varphi + 0.09722$ [kgal-m]

- Result for latitude of the datum point of EVRF2000: -0.08432 [kgal-m]
- causes an undesired shift of the level compared to EVRF2000
- Postulation: points with the same latitude as the datum point of EVRF2000 should get the reduction 0
- final formula for reduction of the datum points:
- $C_{dp2007} = C_{dp95/98} 0.28841 \cdot \sin^2 \varphi 0.00195 \cdot \sin^4 \varphi + 0.09722 + 0.08432$ [kgal-m]



Reduction to a common epoch

EVRF2000:

- Measurements of Finland, Norway and Sweden had been reduced to the epoch 1960
- All other data had not been reduced to a common epoch

EVRF2007

- Reduction to the epoch 2000 by the land uplift model NKG2005LU (Ågren and Svensson)
- Reduction of all points located in the validity area of the model
- datum points are assumed to have velocity zero



NKG2005LU and UELN lines





Comparison of the adjusted heights of EVRF2000 and EVRF2007



Differences in kgal*mm



Contents

- 1. UELN-forerunner Steps of development
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- 3. EVRS and its realization

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- 5. Related projects
- 6. Future next steps



New data since 2008

Russia – European part (2012) extension Latvia (2011) update Spain (2012) update

Report on results of a preliminary adjustment with data status 2012 was held on the EUREF symposium in Paris

Latvia (2012) update (use of own parameters for reducing to epoch 2000)

Germany (2015)

update



Height differences between adjustment 2015 and EVRF2007



Included data changes compared to EVRF2007:

- Russia (new)
- Spain (update)
- Latvia (update)
- Germany (update)
- differences > 3 cm in
 Spain und Portugal

New German leveling data

- Measurements between 2006 and 2012
- 7504 nodal Points
- 7826 leveling lines
- S₀ for 1km leveling: 0.63 kgal·mm (former network 0.85 kgal·mm)
- Border connections
 - 3 to DK (old 3)
 - 5 to PL (old 5)
 - 6 to CS (old 9)
 - 9 to AT(old 11)
 - 13 to CH (old 1)
 - 1 to FR (old 2)
 - 1 to BE (old 2)
 - 14 to NL (old 11)

Epoch difference DE - neighbor

- 23-28 years
 - 3-8 years
- 18-35 years
- 21-39 years
 - 9-54 years
 - 46 years
 - 40 years
- 8-14 years

Height differences because of the change of the German network



Federal Agency for Cartography and Geodesy Included data changes compared to preliminary adjustment 2012:

- Only Germany
- -15 mm in Northern Europe
- 6 mm in South East Europe

Epochs of measurement in UELN





Current configuration and extent of UELN



Parameter of the adjustment

Parameter	UELN 95/98	EVRF2007	Adjustment 2012	Adjustment 2015
Number of datum points:	1	13	13	13
Number of unknowns:	3063	7939	8318	8485
Number of measurements:	4263	10347	10833	11072
Number of condition equations:	0	1	1	1
Degrees of freedom:	1200	2409	2516	2587
A-posteriori standard deviation referred to 1 km levelling distance in kgal·mm:	1.10	1.11	1.19	1.17
Mean value of the standard deviation of the adjusted geopotential numbers (=heights), in kgal·mm:	19.64	16.05	16.47	16.07
Average redundancy:	0.281	0.233	0.232	0.234



Contents

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- 4. News since EVRF2007

5. Related projects

6. Future – next steps



EUVN Densification Action of the European Unified Vertical Network (EUVN_DA)

- GNSS/leveling database consistent with ETRS89 and EVRS
- 25 participating countries, more than 1400 GNSS/leveling points
- Start 2003, finalized in November 2009
- Final report is available at the EUVN_DA website: <u>http://www.bkg.bund.de/EVRS</u> → Related Projects → EUVN_DA
- registered, academic users will get free access to the EUVN_DA database



Height anomaly differences of EUVN_DA and EGG08.

Information system about Coordinate Reference Systems in Europe <u>http://www.crs-geo.eu</u>

Part for height:

- Description of height reference systems in Europe
- transformation parameters from national height reference frame to EVRF2007



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Further activities

- Ukraine
 - 2008 decision to join UELN
 - 2009 selection and preparing of border connections by Ukraine and BKG
 - Since 2010 Data preparation in Ukraine
- Belarus
 - RU prepared data of Belarus
 - 2012 selection and preparing of border connections by Russia and BKG
 - Russia expected leveling data of Germany, Poland, Baltic states in exchange for the Belarus data
 - Providing of leveling data only possible with permission of the owner of the data



Further activities

- France
 - Scientific zero-order leveling network NIREF (not yet available at data center)
 - Tilt between IGN69 and NIREF suspected (23 cm N-S)
 - NIREF contains new border connections to ES, IT, DE, CH, BE
 - only NIREF connected to tunnel measurement to UK
 - France will provide a new data set consisting on NIREF and some new measured lines of IGN69 already 2015
 - Suitable combination of the data of NIREF and IGN69 is needed
- Switzerland
 - New data available, also new border connections to France and Italy
 - Exchange of the data sensibly in combination with new data of Italy and France

Further activities

- Italy (information from national report)
 - Densification and re-measurement of leveling network in Italy since 1996
 - Leveling almost finished
 - Interpolation or measurement of gravity values ongoing
 - Computation of geopotential differences
 - After finishing including in UELN is desired
 - Current Italian leveling data in UELN are obviously different from official height system
- UK
 - Including of tunnel measurement with new data of France possible
 - In UK 3rd leveling epoch was included under constraint in 2nd epoch
 - UELN contains only data of 3rd leveling epoch with N-S tilt, EVRF2007 inconsistent with quasigeoid
 - Including of national heights + offset in UELN? New adjustment isn't necessary because there is only 1 connection to the mainland

Proposal for a new realization of EVRS2007

- A new realization of EVRS should be computed
- New network parts of RU(2008), LV(2011), ES(2012), DE(2015) are already included
- Countries that observed new 1.order leveling data are requested to make them available to the EVRS data center (also such countries that intend to join the UELN)
- Countries that will update their leveling data in the next years are requested to
 - Signalize the upcoming data update and
 - Give an estimate for the date of finishing and possible providing of the data before the next EUREF symposium 2016
- After evaluation of the feedback a date for a new EVRF can be determined



Thank you for your kind attention!

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