Conventions for the Definition and Realization of a European Vertical Reference System (EVRS) – EVRS Conventions 2007 –

Johannes Ihde¹, Jaakko Mäkinen², Martina Sacher¹

1)Federal Agency for Cartography and Geodesy, Frankfurt am Main

2) Finish Geodetic Institute



Outline

- I. Objectives of EVRS 2007
- II. European Vertical Reference System 2000 (EVRS 2000)
- **III.** EVRS 2007 Conventions Definition
- **IV. EVRS Realization Principles**
- V. EVRS 2007 Conventions Realization



- Request of European Commission
- Consideration of user requirements in Europe
- 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

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II. European Vertical Reference System 2000 (EVRS 2000)

- It is prepared by EUREF for adoption by the European Commission to promote widespread use as a de-facto standard for future pan–European GIS data products and services.
- The EVRS is defined as a World Height System (WHS) and realized for practical use as a static system under the name EVRF2000 by
 - the datum of 'Normaal Amsterdams Peil' (NAP)
 - gravity potential differences or equivalent normal heights with respect to NAP.



EVRS 2000 definition (Tromsø)

The European Vertical Reference System (EVRS) is a gravityrelated height reference system. It is defined by the following conventions:

a) The vertical datum is the zero level of which the Earth gravity field potential W_0 is equal to the normal potential of the mean Earth ellipsoid U_0 :

 $W_0 = U_0$.

b) The height components are the differences ΔW_P between the potential W_P of the Earth gravity field through the considered points P and the potential of the EVRS zero level W_0 . The potential difference - ΔW_P is also designated as geopotential number c_P :

 $-\Delta W_P = W_0 - W_P = c_P.$

Normal heights are equivalent to geopotential numbers.

c) The EVRS is a zero tidal system¹, conforming to the IAG Resolutions No 16 adopted in Hamburg in 1983

<u>datum</u>

geocentric, including oceans and atmosphere

*W*₀ independent from the tidal system (Bursa)

coordinate system

SI units $m^2 \cdot s^{-2}$ $W_p = U_p + T_p (BVP)$ $W_p = W_0 - c_p (levelling)$ $H_n = \frac{c_p}{\overline{\gamma}}$

<u>frame</u>

¹⁾ In a) and b) the potential of the Earth includes the potential of the permanent tidal deformation but excludes the permanent tidal potential itself.



a) The vertical datum of the EVRS is realized by the zero level through the Normaal Amsterdams Peil (NAP). Following this, the geopotential number in the NAP is zero:

$$c_{NAP}=0.$$

b) For related parameters and constants the Geodetic Reference System 1980 (GRS80) is used. Following this the Earth gravity field potential through NAP W_{NAP} is seed the normal potential of the GRS80

$$W_{NAP}^{REAL} = U_{0GRS80}$$

c) The EVRS2000 datum is fixed by the geopotential number 7.0259 m² s⁻² and the equivalent normal height 0.71599 m² of the reference point of the UELN No. 000A2530/13600.



The adjustment of geopotential numbers was performed as an unconstrained adjustment linked to the reference point of UELN 73 (in NAP). In January 1999, the adjustment version UELN 95/13 was handed over to the participating countries as the UELN 95/98 solution.



United European Levelling Network 1995 (UELN-95/98)



Should the W₀ value be changed?



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The consequences have to be considered!



The European Vertical Reference System (EVRS) 2007 is a kinematical height reference system. The EVRS definitions fulfils the following four conventions:

1. The vertical datum is defined as the equipotential surface for which the Earth gravity field potential is constant:

 $W_0 = W_{0E} = const.$

And is in the level of the Noormals Amsterdam Peil.



- The unit of length of the EVRS is the meter (SI). The unit of time is second (SI). This scale is consistent with the TCG time coordinate for a geocentric local frame, in agreement with IAU and IUGG (1991) resolutions. This is obtained by appropriate relativistic modelling.
- 3. The height components are the differences ΔW_P between the potential W_P of the Earth gravity field through the considered points P and the potential of the EVRS conventional zero level W_0 . The potential difference ΔW_P is also designated as geopotential number c_P :

$$-\Delta W_P = c_P = W_{0E} - W_P.$$

Normal heights are equivalent to geopotential numbers.

4. The EVRS is a zero tidal system, in agreement with the IAG Resolution No 16 adopted in Hamburg in 1983.



IV. EVRS Realization – Principles

- (1) Network New adjustment of the UELN
- (2) Datum specifications Keeping the European vertical datum - NAP level - of UELN95/98 at Epoch 2000
- (3) Reduction of data Tidal system
- (4) Time evolution using ECGN

Observation of vertical movements of UELN points against the conventional value W_{OE}

(1) EVRS Datum

Keeping the vertical datum European NAP level of UELN95/98 at Epoch 2000 by fitting the UELN07 (free) adjustment to the UELN95/98 solution by identical points: $\sum_{n=1}^{n} (c_{n-1} - c_{n-1}) = 0$

$$\sum_{i=1}^{1} (c_{P2007} - c_{P95/98}) = ($$

The EVRS 2007 geopotential number of each datum point after fitting realize the EVRS datum.

Selection of a couple (10 - 15) of identical points for which it can assumed, that they are stable marked and located in the stable part of the European part plate and connected by precise measurements.



(2) EVRS vertical components – geopotential numbers and normal heights

(a) New adjustment of the UELN network using all current available levelling and gravity observations reducing to the epoch 2000

 $\boldsymbol{C}_{\boldsymbol{P}\boldsymbol{E}} = -\Delta \boldsymbol{W}_{\boldsymbol{P}\boldsymbol{E}} = \boldsymbol{W}_{\boldsymbol{O}\boldsymbol{E}} - \boldsymbol{W}_{\boldsymbol{P}}.$

(b) GNSS levelling

using GNSS vertical components in ITRF/ETRS89 – GRS80 and a EVRS aligned European Geoid EGG07

$$c_{PE} = -\Delta W_{PE} = W_{0E} - W_{P} = W_{0E} - U_{P} - T_{PGGM}$$
$$= W_{0E} - U_{0} - \partial U_{0} / \partial h \cdot h_{ITRF} - T_{P}$$

GGM

$$= - \partial U_0 / \partial h \cdot h_{ITRF} - T_{PEGG}$$
$$(H_E = h_{ITRF} - N_{EGG})$$



Both the geopotential numbers and the normal heights of EVRS 2007 were handed over to the participating countries. Nevertheless, each country can convert the geopotential numbers in any height system for its own use. The formula for the normal heights H_n is

$$H_n = \frac{c_P}{\overline{\gamma}}$$

where is the average value of the normal gravity along the normal plumb line between the ellipsoid and the telluroid and between the quasigeoid and the earth surface respectively.

The average value of the normal gravity along the normal plumb line is determined by

$$\overline{\gamma} \approx \gamma_{\rm m} = \gamma_0 - \frac{0.3086 \,\mathrm{mgal/m} \cdot \mathrm{h}}{2} + \frac{0.072 \cdot 10^{-6} \,\mathrm{mgal/m}^2 \cdot \mathrm{h}^2}{2}$$

with the Gravity Formula 1980 and latitude in ETRS89.



Time varying observations should to be reduced to Epoch 2000 and to zero tidal system.

If the UELN 2007 levelling observations have no tidal corrections, the EVRS 2007 geopotential numbers are approximately given in mean tidal system.

The EVRS vertical components are delivered in zero tidal system and mean tidal system.

Observation of vertical movements of EVRS against a conventional value W_{0E} by time series observations of the ECGN as carrier network of the European Vertical Reference Frame and its datum.

Under the condition,

 $V_{hi} = V_{Hi}$

the velocities of the physical heights *H* can be derived from time series of the the ITRFxx heights *h*: $H_{P}(t) = H_{P}^{0} + \dot{h}_{P}^{0}(t-t^{0})$