Federal Agency for
Cartography and Geodesy

Definition and Realization of the EVRS: How do we want to proceed?

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EUREF Symposium 2014
June 04-06, 2014, Vilnius, Lithuania

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EVRS Definition

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

1.The vertical datum is defined as the equipotential surface for which the Earth gravity field potential is constant: Zero Level (Datum)

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

And is in the level of the Noormals Amsterdam Peil.

2. 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. Units

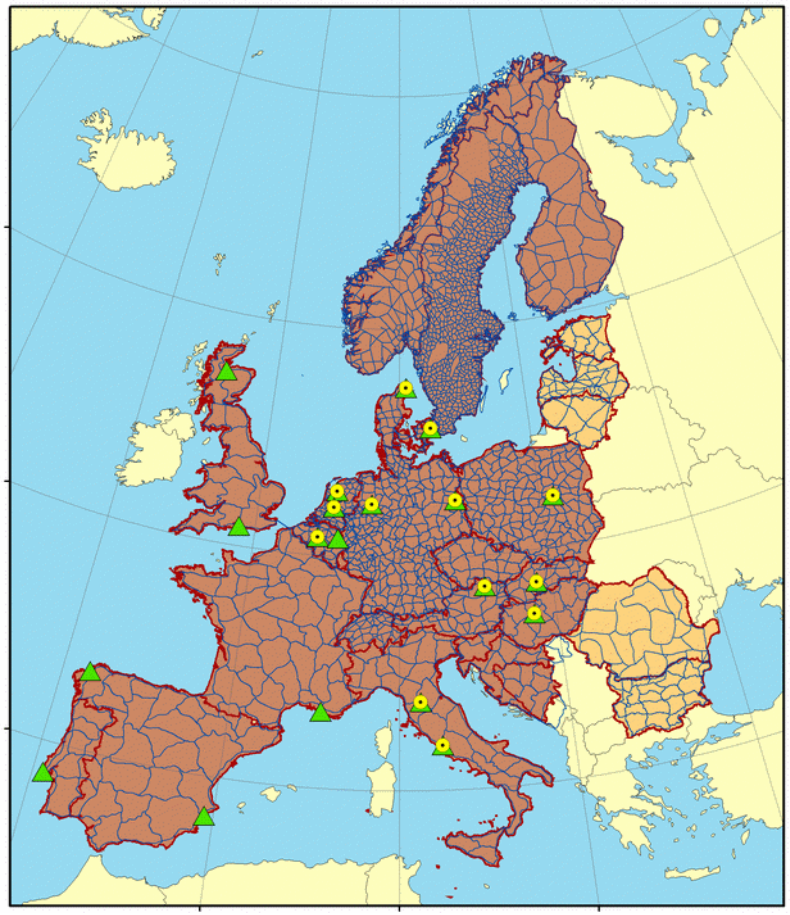
3.The height components are the differences ΔW_P between the potential W_P of the Earth gravity field through the considered points P and the potential of the EVRS conventional zero level W_0. The potential difference ΔW_P is also designated as geopotential number c_P: Kind of heights

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

The metric equivalent is the normal height.

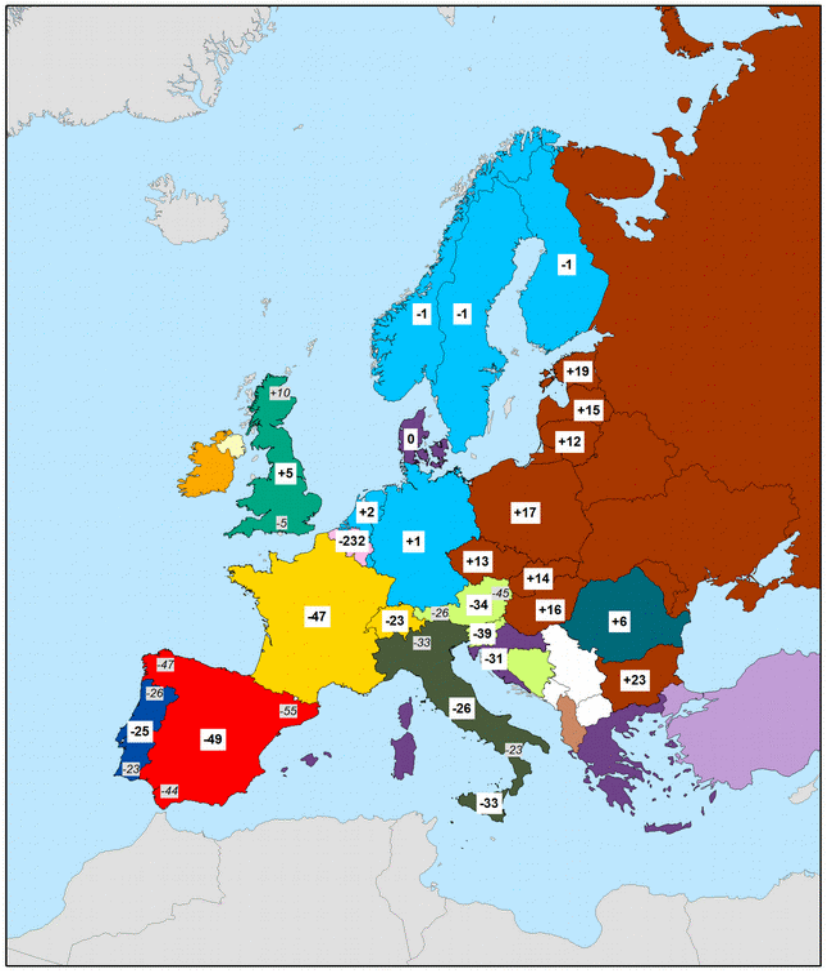
4. The EVRS is a zero tidal system, in agreement with the IAG Resolution No 16 adopted in Hamburg in 1983. Permanent earth tides

European Vertical Reference Frame 2007 - EVRF2007



- Released 2008 in Brussels
- 27 countries
- 13 datum points
- 7939 nodal points
- 10347 lines
- s_0 = 1.11 kgal·mm
- Zero tide
- Epoch 2000 (Modell NKG2005LU)
  http://www.bkg.bund.de/EVRS
- Results, provided to the participating countries (geopotential numbers, normal heights, standard deviation, measurement related data)

Transformation parameter



Estimation of 3 parameters (plane) as transformation parameters between the national vertical reference frames and EVRF2007

$$H_{EVRF\,2007} - H_{NVRF} = m_1 - e + \left[m_2 M_0 (\varphi_i - \varphi_0) + m_3 N_0 (\lambda_i - \lambda_0)\right]$$

m_1 height offset

m_2, m_3 tilt (North-South, West-East)

φ_0, λ_0 coordinates of reference point P_0

M_0, N_0 radius of curvature in meridian and perpendicular to the meridian in P_0

http://www.crs-geo.eu

Reference tide gauges

Alicante	Cascais	Kronstadt	Ostend
Amsterdam	Constanta	Malin Head	Trieste
Antalya	Durres	Marseilles	other
Belfast	Genoa	Newlyn	no information

New Data in UELN since EVRF2007

New Data

- data already used in a preliminary adjustment 2012
  - 2009 Russia (leveling network of European part of Russia)
  - 2011 Latvia
  - 2012 Spain
- Data available but not included yet
  - 2014 Germany

Known Activities, but no data at the UELN data center

- France (information about zero-order leveling network NIREF (1983-2011?), tilt between IGN69 and NIREF, N-S bias in IGN69 suspected (23 cm)
- Belarus (via Russia)
- Ukraine (data preparation)
- Italy (Re-observation of 1.O. Leveling network in combination with gravity)
- Estonia (Re-observation of 1.O. Leveling network until 2013?)

New Data in UELN since EVRF2007

	Russia	Latvia	Spain	Germany
	new	replacement	replacement	replacement
Measurement epoch	1967-2006	2000-2011 (reduced to epoch 2007)	2001-2008	2006-2012
m_0	2.06 kgal·mm	0.74 kgal·mm (old 1.71 kgal·mm)	2.40 kgal·mm (old 1.79 kgal·mm)	0.63 kgal·mm (old 0.83 kgal·mm)
Remark	40 years old border connections to the Baltic States		New leveling lines, only a few identical points	

Do we need a new EVRF?

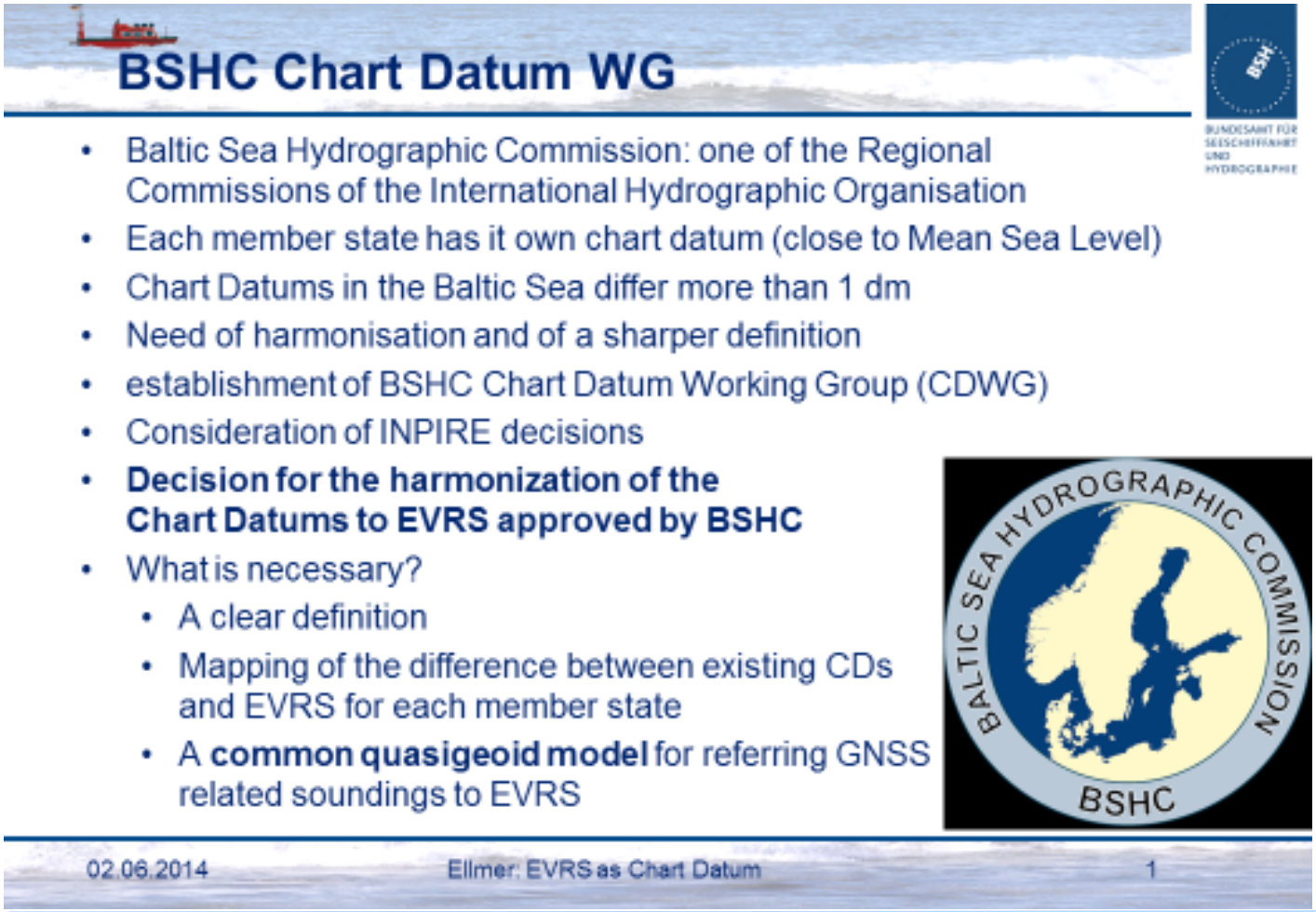
- New national vertical reference frames base on leveling observations (except Great Britain). New national leveling networks should be included.
- Does anybody really use benchmarks with heights in EVRF2007?
- The transformation parameters between EVRF2007 and the national vertical reference frames can be used.
- INSPIRE
- Use of EVRS or national vertical reference frames in Poland, Latvia and Lithuania (presentations of Ryczywolski, Aleksejenko, Ladukas et. al.)

Quelle: Wladyslaw (http://de.wikipedia.org/wiki/Hochrheinbr%C3%Bcke)

Example: Bridge over the river Rhine between Switzerland and Germany

Do we need a new EVRF?

User interest in an official quasigeoid product for EVRF will probably increase



How we realize the next EVRF?

Leveling approach and/or gravity field approach

Leveling approach	Gravity field approach
Levelings and gravity observations	Geoid/quasigeoid model and GNSS
▪ heights on leveling benchmarks and/or ▪ transformation parameter between EVRF and the National VRV	▪ benchmarks not necessary ▪ heights on GNSS-benchmarks can be provided for leveling applications
▪ Traditional approach used for EVRF and national vertical reference frames ▪ Geographical restrictions ▪ Different and long observation epochs ▪ Possible systematic errors ▪ effort, cost-intensive	▪ Improved global gravity field models ▪ GNSS positioning service is necessary for operational application ▪ Some countries have already adopted vertical reference frames based on this approach (e.g. Canada)
▪ Vertical reference frame is based on leveling ▪ Model of the height reference surface for GNSS based height determination a) Gravimetric geoid or quasigeoid, e.g. EGG08 b) hybrid or combined model (a + “interpolation surface” which reduces systematic differences at GNSS/leveling points)	

EVRS conventions

Datum defintion and realization

- Background: Activities to establish a World Height System
- Which zero Level?
  - NAP (EVRS, 6 countries in Europe adopted NAP as their national vertical datum)
  - Zero level of a possible future world height system (Global Mean Sea Level)
  - Any other level …
- How do we realize this level?
  - Datum points (benchmarks) and their normal heights or geopotential number of the last EVRF realization
  - Conventional geopotential value W
    - W_0 value of the current IERS convention (e.g. Canada, USA) or a possible future update
    - Determination of a conventional geopotential value for NAP W_{NAP} and fix this value for the future
    - $W_0 = U_{0\ (GRS80)}$
- Which geopotential model and/or which benchmarks should be used?
- How do we handle possible height changes of the datum points in future?
- Which products can be provided?

EVRS conventions

Solid earth tides (permanent tides)

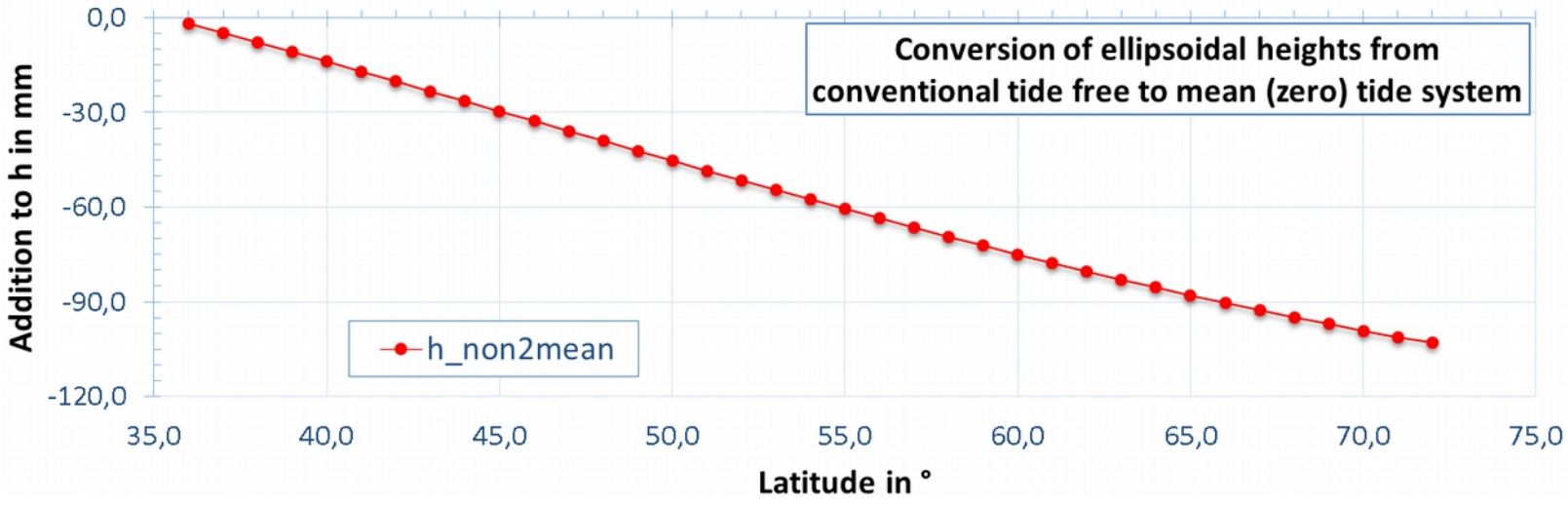
- Conventional tide free, zero tide or mean tide
- Current situation is heterogeneous
  - IAG recommendation 1983: zero tide
  - Geopotential models, gravimetric geoid or quasigeoid models: zero tide
  - EVRS convention: zero tide
  - EVRF2007: zero tide
  - EVRF2000 and earlier: mean tide
  - Most national vertical reference frames in Europe: No correction applied (mean tide)
  - GNSS: conventional tide free
  - User expectation: mean tide?

Austria	mean tide
Belgium	mean tide
Croatia	mean tide
Czech Republic	mean tide
Denmark	tide free
Finland	zero tide
France	mean tide
Germany	mean tide
Great Britain	mean tide
Hungary	mean tide
Italy	mean tide
Netherlands	tide free
Norway	zero tide
Poland	tide free
Portugal	mean tide
Slowakia	mean tide
Slowenia	mean tide
Spain	mean tide
Sweden	zero tide
Switzerland	mean tide
not in EVRS:	
Ireland	tide free
Luxembourg	zero tide
Turkey	tide free

EVRS conventions

Solid earth tides

- How do we handle this situation, what do we prefer?
  - Convince GNSS-community to change their convention (change of ITRS and ETRS conventions!)
  - Adopt tide free for physical heights
  - Computation of the effect (tide free versus zero tide resp. tide free versus mean tide for the ellipsoidal heights) and consider it as an additional correction to a gravimetric quasigeoid



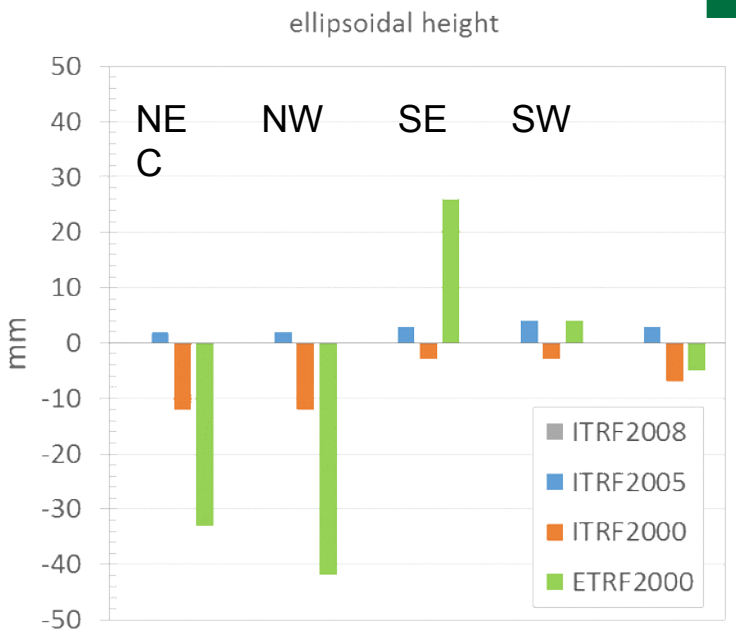
ETRS89 Datum Realization

- Model of the height reference surface can only be related to certain ETRF realization!
- Recommendation of EUREF TWG ETRF2000
  - Transformation from current ITRFxx → ITRF2000 using the 14 parameter published in the memo of Boucher and Altamimi (e.g. ITRFxx used for the satellite orbits of the GNSS campaign)
  - Transformation ITRF2000 → ETRF2000 using a 6 parameter transformation (3 rotation rates and 3 translations estimated from 14 transformation parameters between ITRF2000 and ITRF89 for the barycenter of the European network)

$$X^E(t_c) = X^I_{YY}(t_c) + T_{YY} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \cdot X^I_{YY}(t_c) \cdot (t_c - 1989.0)$$

ETRS89 datum transformation

- Influence of the transformation from ITRFxx to ETRF2000 on the ellipsoidal heights in Europe
  - ITRF2008 and ITRF2005: almost identical (some mm)
  - ITRF2005 and ITRF2000: shift and slope in north-south direction (1 cm level)
  - ITRF2000 and ETRF2000: variations caused by the translation parameter (4 cm level)
- These effects exceed the accuracy level of the gravimetric quasigeoid and have to be taken into account as an additional effect in the height reference surface



	B	L	h (ITRF2008) [mm]	h (ITRF2005) [mm]	h (ITRF2000) [mm]	h (ETRF2000) [mm]
north east (NE)	70	30	0	2	-12	-33
north west (NW)	70	-10	0	2	-12	-42
south east (SE)	36	30	0	3	-3	26
south west (SW)	36	-10	0	4	-3	4
Center (C)	50	10	0	3	-7	-5

Transformation tool: http://www.epncb.oma.be/_productsservices/coord_trans/index.php

Agreement of gravimetric geoid, ellipsoidal and physical heights - Two examples

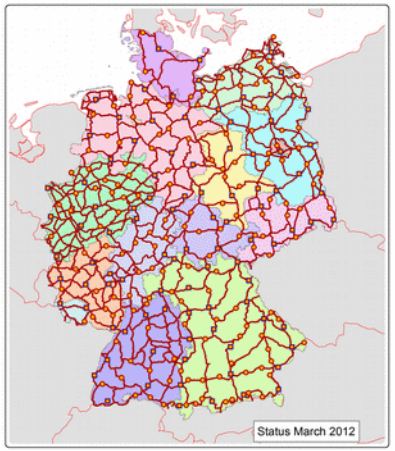
ESA Project GOCE+ Height System Unification

Investigation of the impact of GOCE on the unification of height systems

Project partner
- Technical University Munich
- University of Calgary
- National Oceanographic Center Liverpool
- BKG

Modernization of the German vertical reference system

Different observations during the common epoch 2006-2012
- Leveling (30.000 km)
- GNSS observations (ca. 250 benchmarks and 300 permanent stations)
- Absolute gravity (ca. 250 points)
- Validation and densification of terrestrial gravity data (1 point per 4x4 km²)
- Adoption of new realizations of all reference frames
  - Vertical
  - Spatial
  - Supply of a new quasigeoid model
  - Transformation surface between DHHN2012 and DHHN2016



Agreement of gravimetric geoid, ellipsoidal and physical heights – error budget

Gravity field model ζ^{grav}

- High resolution quasi geoid model EGG2008

Long wavelength improved by GOCE using a Gaussian filter

- Satellite-only global gravity field models, e.g. GOCO03S d/o 250 and TIM-R4

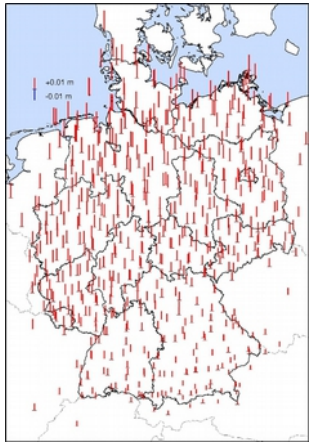
Ellipsoidal heights h and physical Heights H

- EUVN-DA data set
  - 1316 points in ETRS89/ETRF2000? (Kenyeres et al., IAG Symposia 135, 2010)
  - Physical height in the national vertical reference frame (tidal system of 23 European countries transformed to zero tide)
- Germany
  - 272 points from the DHHN project 2006-2012
  - Ellipsoidal heights in ITRF2005 and ETRF2000
- All ellipsoidal and physical heights transformed in the zero tide system

$$r = h - H - \zeta^{grav}$$

Example Germany

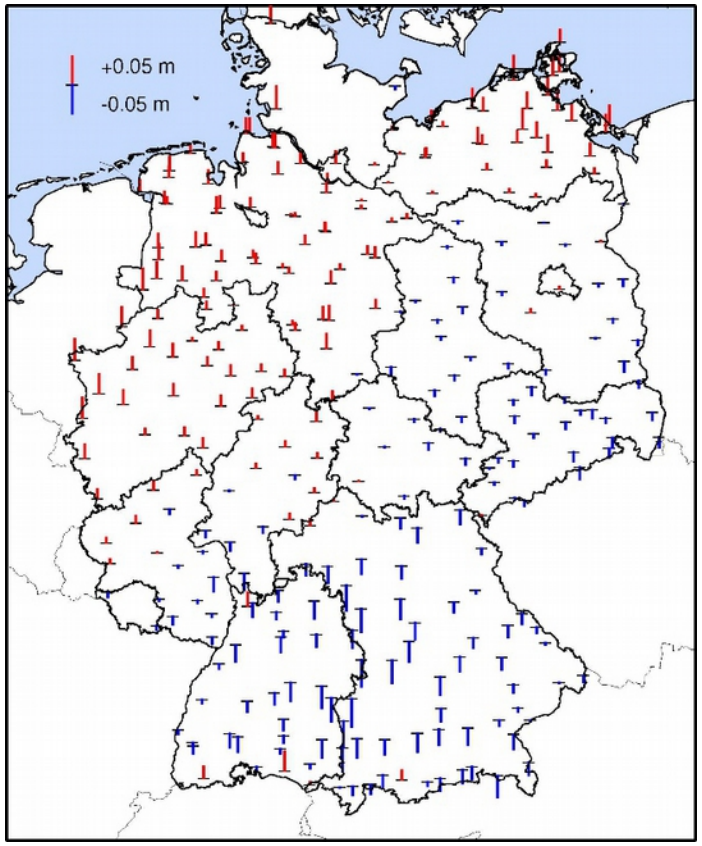
- Better agreement of levelings and gravimetric geoid to ITRF2005 than to ETRF2000
- Experiences in other countries?
- Remaining tilt



GNSS-solution	TIM_R4 + EGG08	
	s_r [cm]	s_r [cm] (plane subtracted)
ITRF2005	1.99	1.26
ETRF2000	2.24	1.26

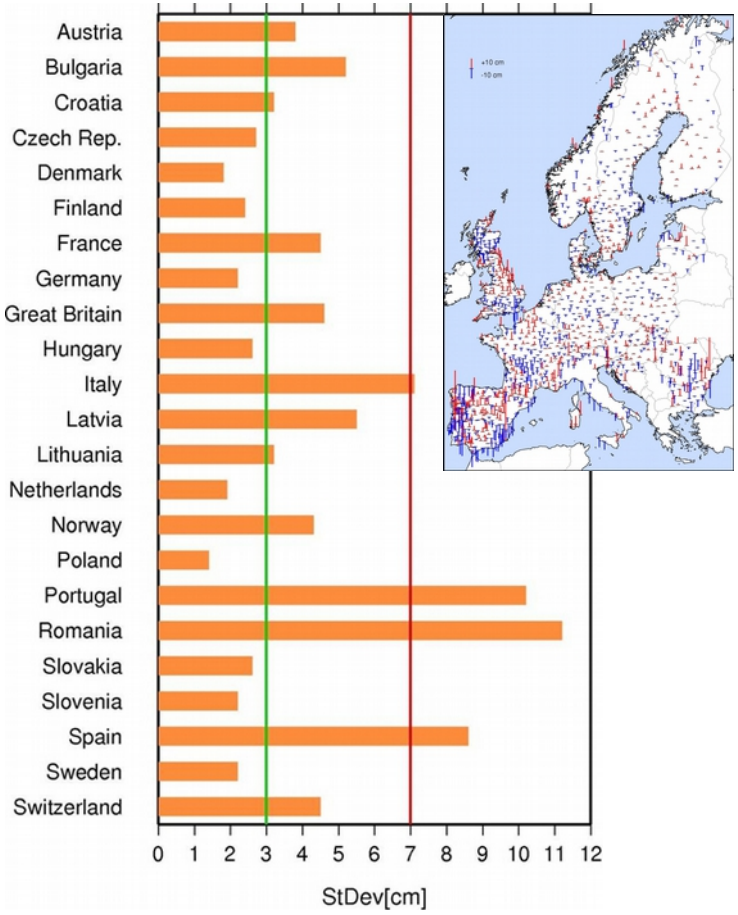
Difference of ellipsoidal height ITRF2005 and ETRF2000

Residuals ITRF2005



Example EUVN-DA

- Good agreement
- Standard deviation of residuals
  - 10 countries below 3 cm
  - 10 countries between 3 cm and 7 cm
  - Only 3 countries above 6 cm
- Can be improved taken into account
  - Differences between ITRF and ETRF
  - Future European quasigeoid model
  - …



Summary

- The EVRS/EVRF can/will gain in importance and practical relevance (e.g. INSPIRE, CDWG).
- Further updates of EVRF are necessary
- Progress in global and regional gravity field modelling opens new possibilities for the realization vertical reference frames
- A decision how we want to proceed concerning the EVRS conventions and its realizations is necessary
- Background: activities for the definition and realization of global Vertical Reference System, e.g. Draft of the Conventions for the Definition and Realization of a Conventional Vertical Reference System (CVRS) 2007
- Personal summery
  - New adjustment of UELN because most national vertical reference frames in Europe base on these leveling networks

Summary

- Personal summery (continued)
  - In addition a model of the European vertical reference surface should be provided to support an easy access to the EVRF by the costumer (GNSS-height determination)
  - This would open the possibility to include countries or islands, which are not part of the United European Leveling Network.
  - Vertical reference surface base on the European gravimetric quasigeoid
  - correction surface is probably necessary (takes into account different solid earth tide conventions and differences ITRF ↔ ETRF, …)
  - Improvement of the gravity data base for the European geoid determination
  - Experiences and investigations of other countries would be valuable
  - Information exchange about the national geoid/quasigeoid models and comparison of these models
  - European database with coordinates/heights in ETRF, EVRF and national vertical reference frames (update and extension of EUVN-DA?)
  - Extension of the data base about the coordinate reference systems in Europe (CRS-EU)

Thank you for your kind attention!

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