The European Vertical Reference Frame and the Relationship to the New Icelandic Vertical Reference

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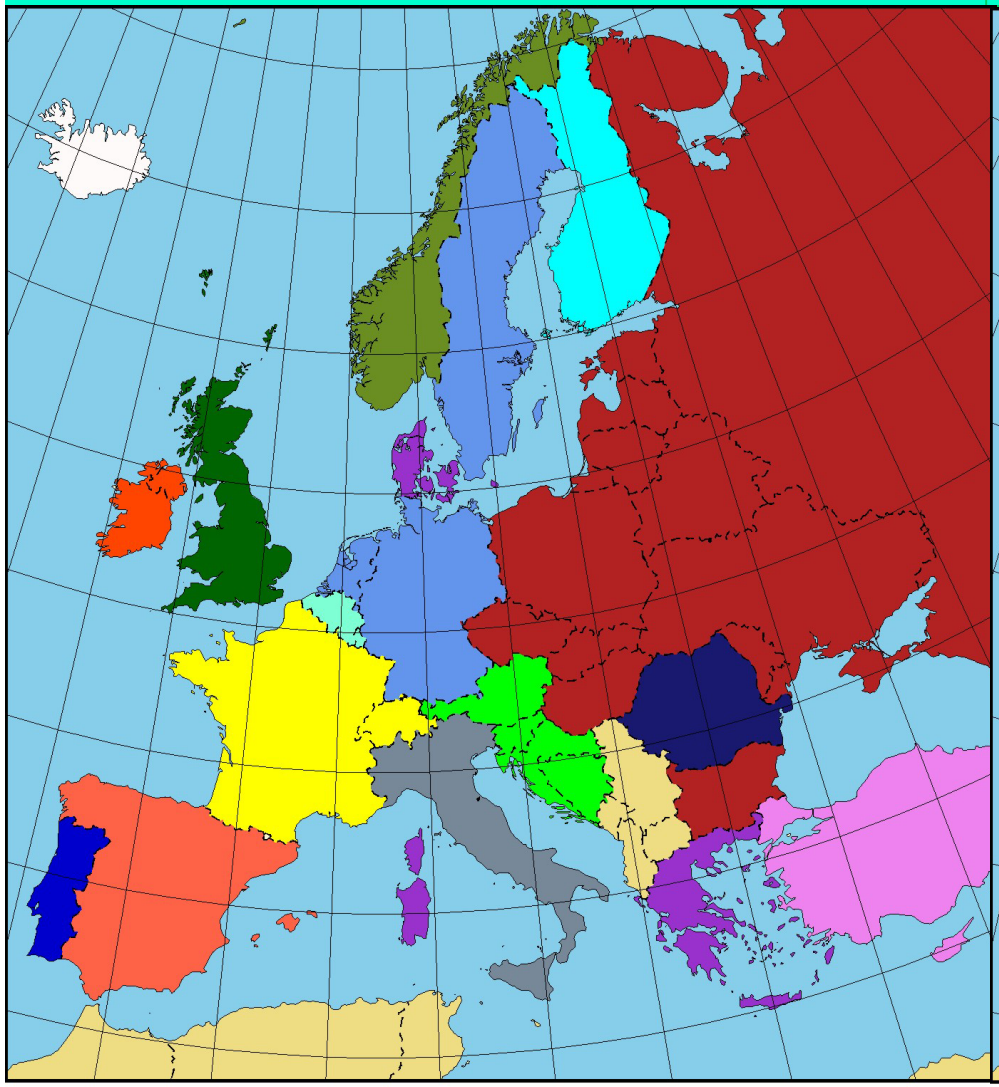
Germany

NGK Workshop
"The Establishment of a New Vertical Reference for Iceland"
June 15th-16th, 2005 in Reykjavík, Iceland

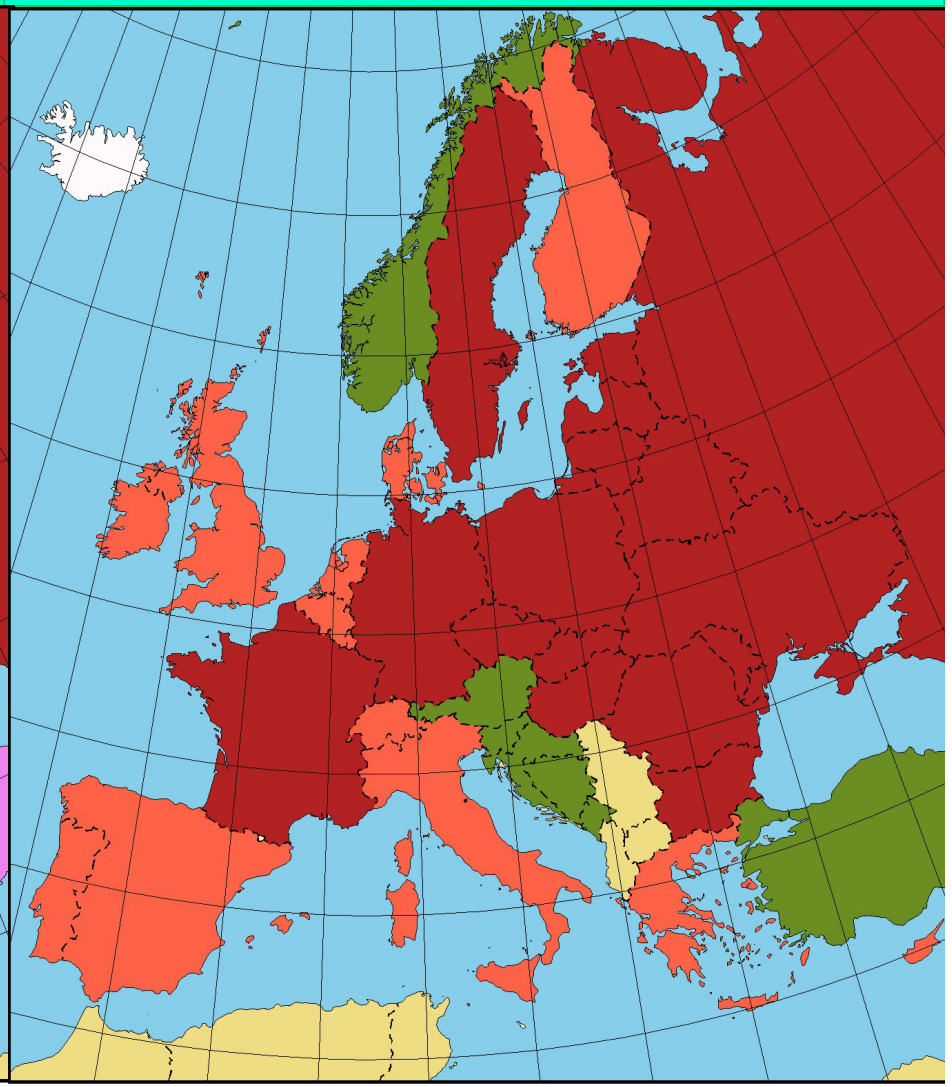
Reference Tide Gauges of National Height Systems in Europe



July 01, 1998

Alicante
Amsterdam
Antalya
Cascais
Constanta
Genova
Helsinki
Kronstadt
Malin Head
Marseille
Newlyn
Ostende
Tregde
Trieste
no information
other

Kind of Heights of National Height Systems in Europe



July 01, 1998

normal heights
orthometric heights
normal orthometric heights
no information
no levelling heights

bkg

The European Vertical Reference Frame and the Relationship to the New Icelandic Vertical Reference

(1) The United European Levelling Network UELN-95/98

(2) Integrated Networks - The European Vertical Reference Network EUVN

(3) The European Vertical Reference Frame EVRF2000

(4) European Combined Geodetic Network ECGN

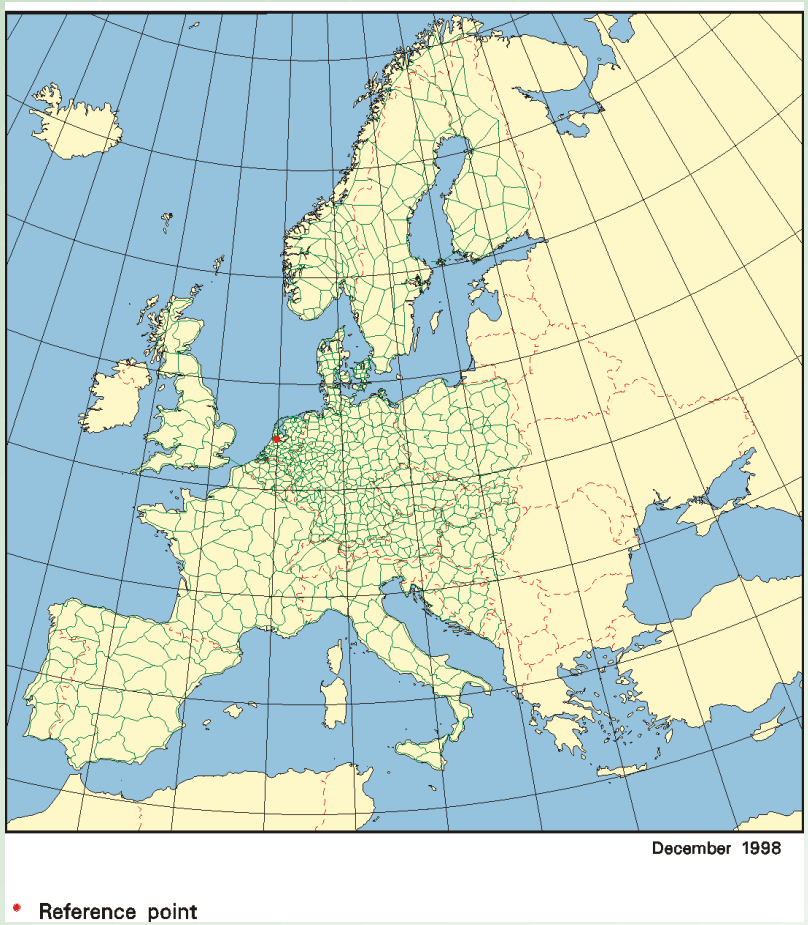
(5) The Information System for European Coordinate Reference Systems (CRS)

(6) EVRF/UELN2006 and the Relationships to the New Icelandic Vertical Reference

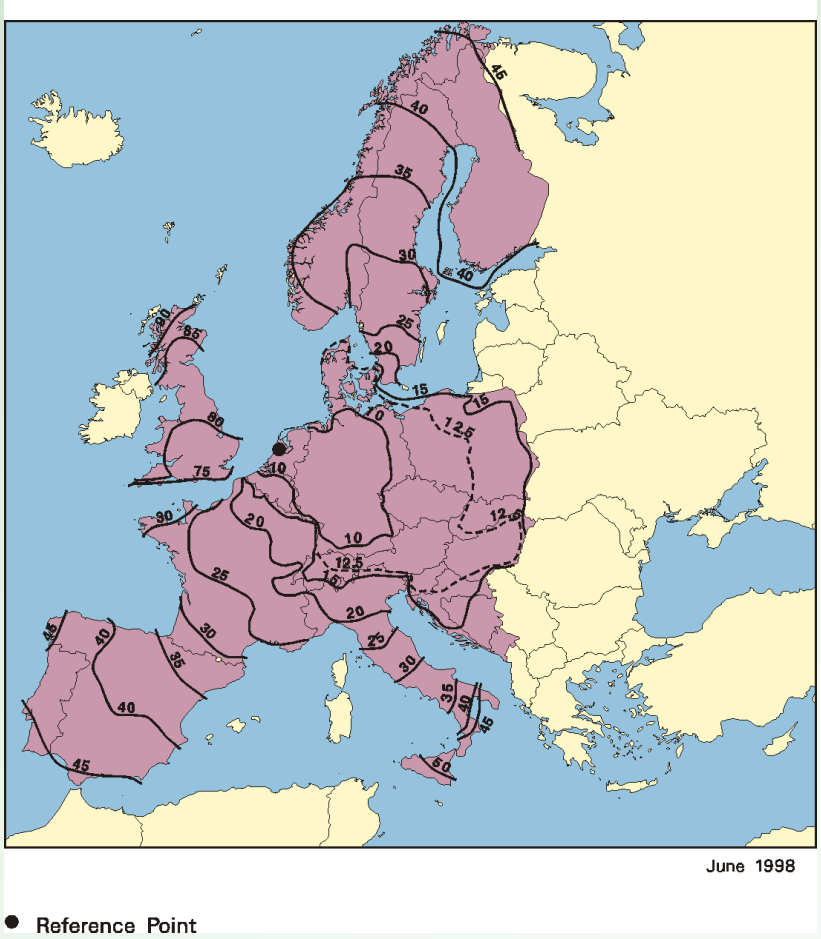
(1) The United European Levelling Network UELN-95/98

Adjustment version UELN-95/13 is the UELN-95/98 solution.

Unconstrained adjustment linked to the reference point of UELN-73 (NAP).

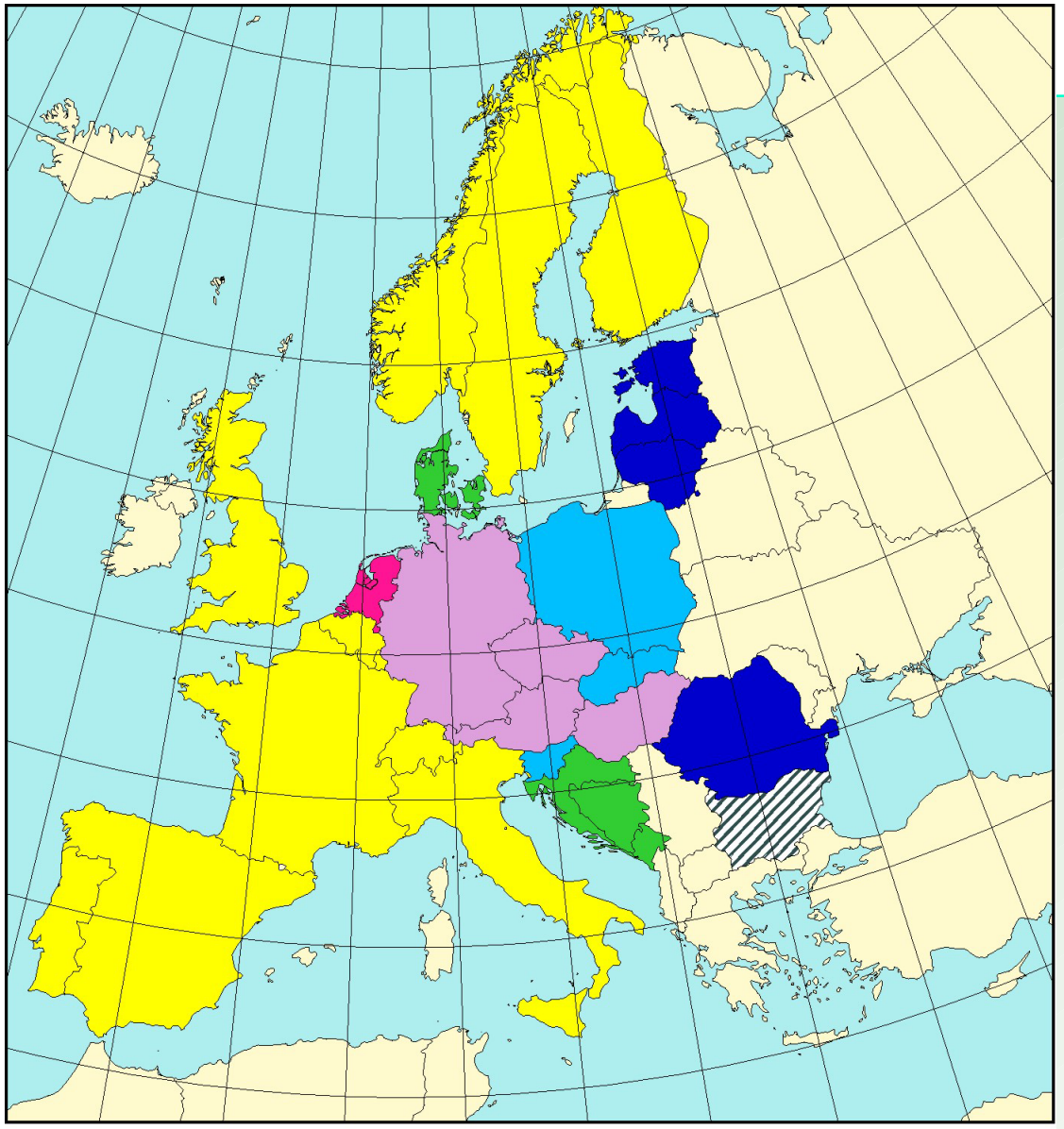


United European Levelling Network 1995 (UELN-95/98)



UELN 95/98 – Isolines of Precision [kgal · mm]

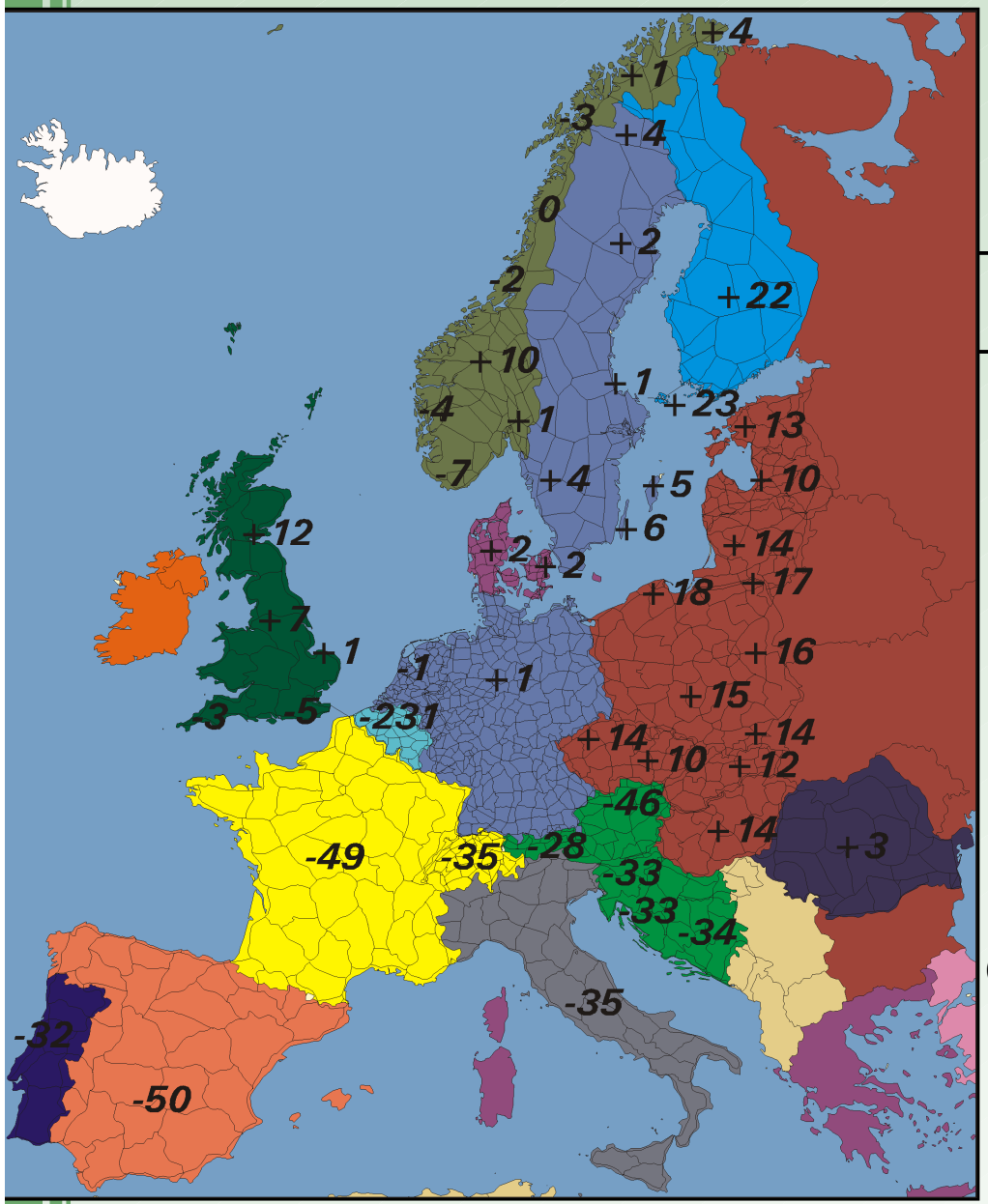
UELN 95
Enlargement

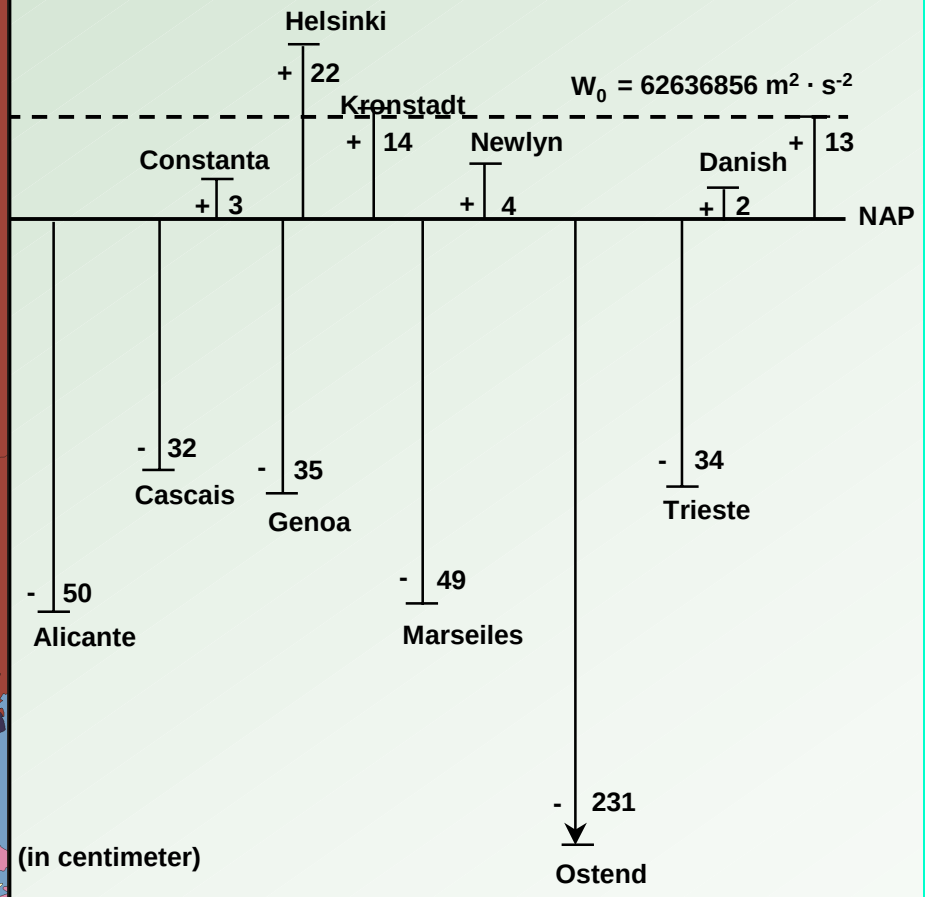


September 2000

- UELN-73/86 / UELN-/73/94 (Adjustments 1986 and 1994)
- UELN-95/1, -95/2, -95/3, -95/4, -95/5 (Adjustments 1995)
- UELN-95/6, -95/7, -95/8 (Adjustments 1996)
- UELN-95/9, -95/10 (Adjustments 1997)
- UELN-95/11, -95/12, -95/13 (Adjustments 1998)
- UELN-95/14, -95/15 (Adjustments 1999 and 2000)
- Future steps

Transformation from National Height Datums to NAP





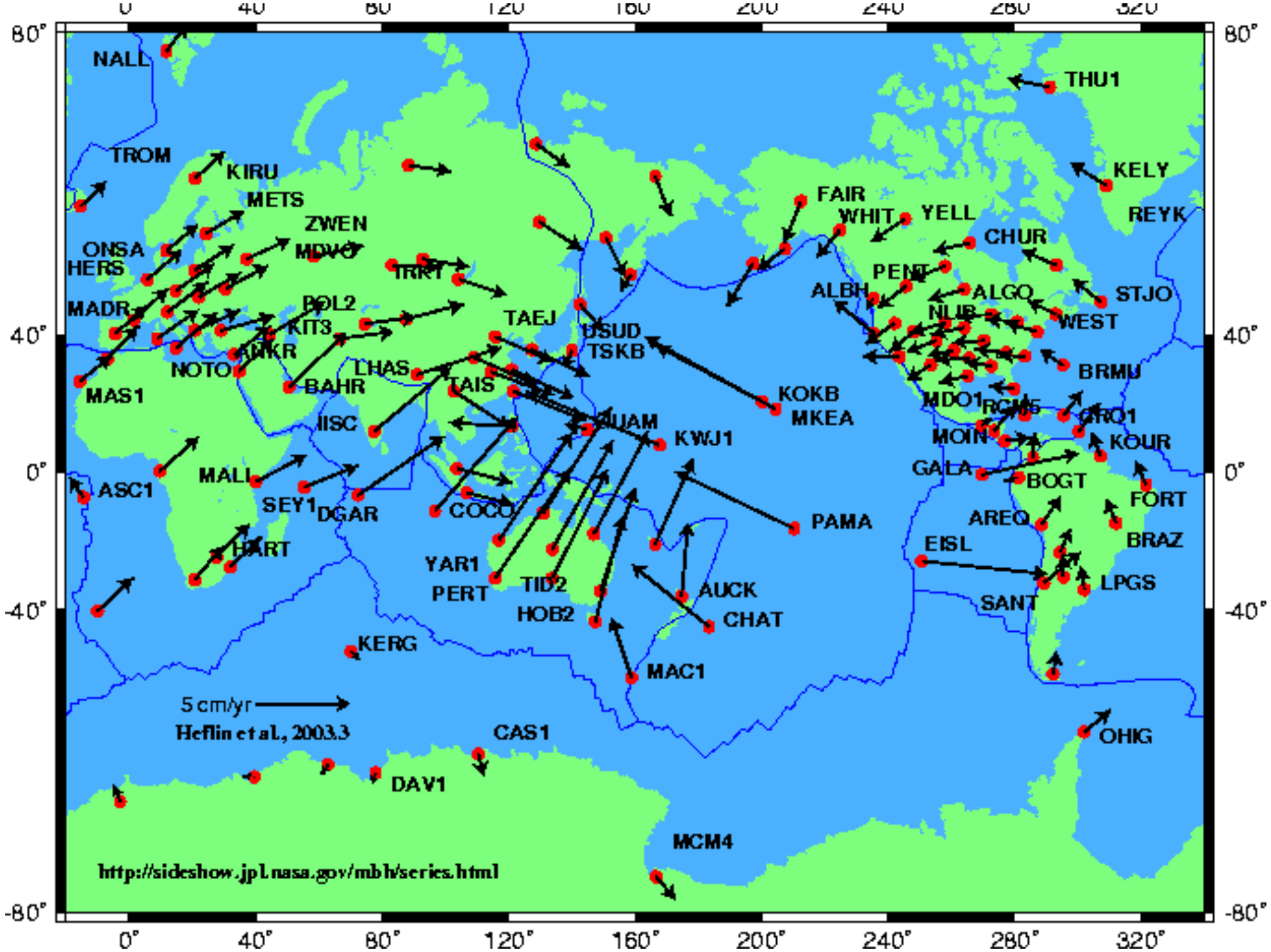
(2) Integrated Networks

Thesis

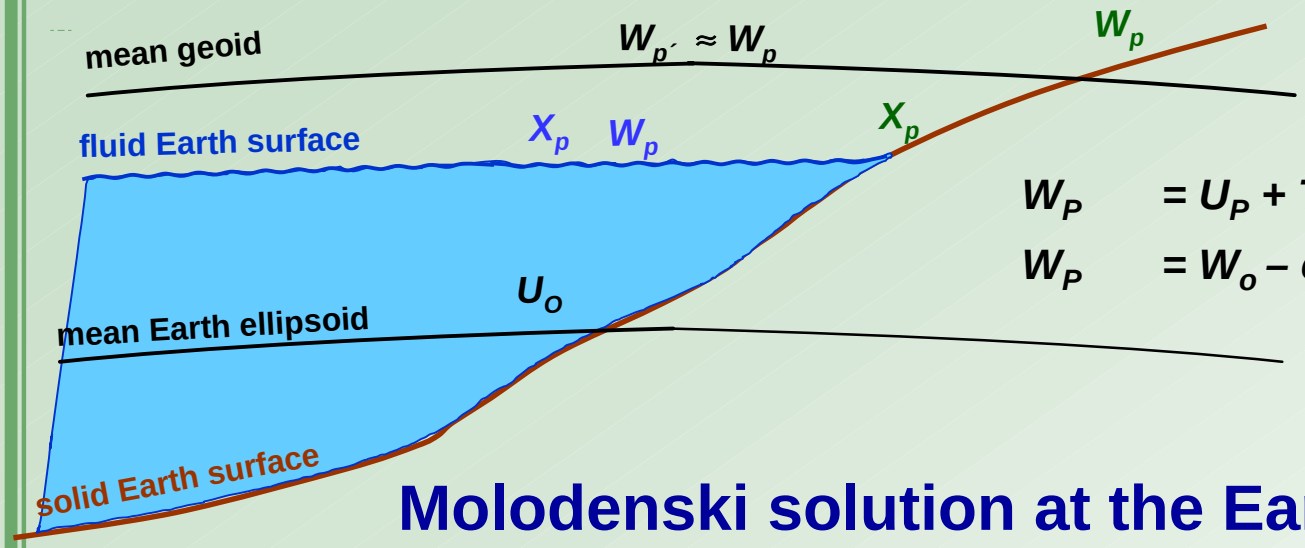
The Earth surface is determined by its geometry X_P and the potential of the Earth gravity field W_P on it.

Geodesy is global.

All is in movement – there is no fix point.


0
40
80
120
160
200
240
280
320
80°
40°
0°
-40°
-80°
NALL
TROM
KIRU
METS
ZWEN
MDVO
ONSA
HERS
MADR
TRRT
POL2
KIT3
ANKR
NOTO
BAHR
LHAS
TAEJ
TAIS
DSUD
TSKB
KOKB
MKEA
GUAM
KWJ1
PAMA
IISC
MAS1
ASC1
MALI
SEY1
DGAR
COCO
HART
YAR1
PERT
TID2
HOB2
AUCK
CHAT
MAC1
KERG
CAS1
DAV1
MCM4
5 cm/yr
Heflin et al., 2003.3
http://sideshow.jpl.nasa.gov/mbh/series.html
THU1
KELY
REYK
FAIR
WHIT
YELL
CHUR
PENT
ALBH
ALGO
STJO
NLIB
WEST
BRMU
MDO1
RCM5
GRO1
MOIN
KOUR
GALA
BOGT
FORT
AREQ
BRAZ
EISL
LPGS
SANT
OHIG

Height Determination (X_P , W_P)



$W_P = U_P + T_P$ (BVP Molodenski)

$W_P = W_o - c_P$ (levelling)

Molodenski solution at the Earth surface P

levelling

$$c_P = W_0 - W_P = \int_o^P g\,dh$$

$W_P = W_o - c_P$

BVP

$$T_P = \frac{R}{4\pi}\int_\sigma (\Delta g + G_1 \ldots) S(\psi)\, d\sigma$$

$W_P = U_P + T_P$

spatial

X_P

h_P (U_0)

physical heights

$$H_o = \frac{c_P}{\bar{g}} \qquad H_n = \frac{c_P}{\bar{\gamma}}$$

height anomalies

$$\zeta = \frac{T_p}{\gamma_Q} = \frac{W_P - U_P}{\gamma_Q}$$

ellipsoidal heights

$$h_P = H_P + \zeta_p$$

Integrated Geodetic Network = 4D Networks

Needs combination of various geodetic methods

- levelling / repeated (UELN)

$$\Delta h_{ij}(t_k) + \varepsilon_{\Delta Hijt} = H_{j,ref} + \Delta t_k \cdot v_j - (H_{i,ref} + \Delta t_k \cdot v_{Hi})$$

- GPS / permanent (EPN)

$$v_{hi} + \varepsilon_{vhi} = v_{hi} \quad \text{with the convention } v_{hi} = v_{Hi}$$

- gravity / permanent and repeated

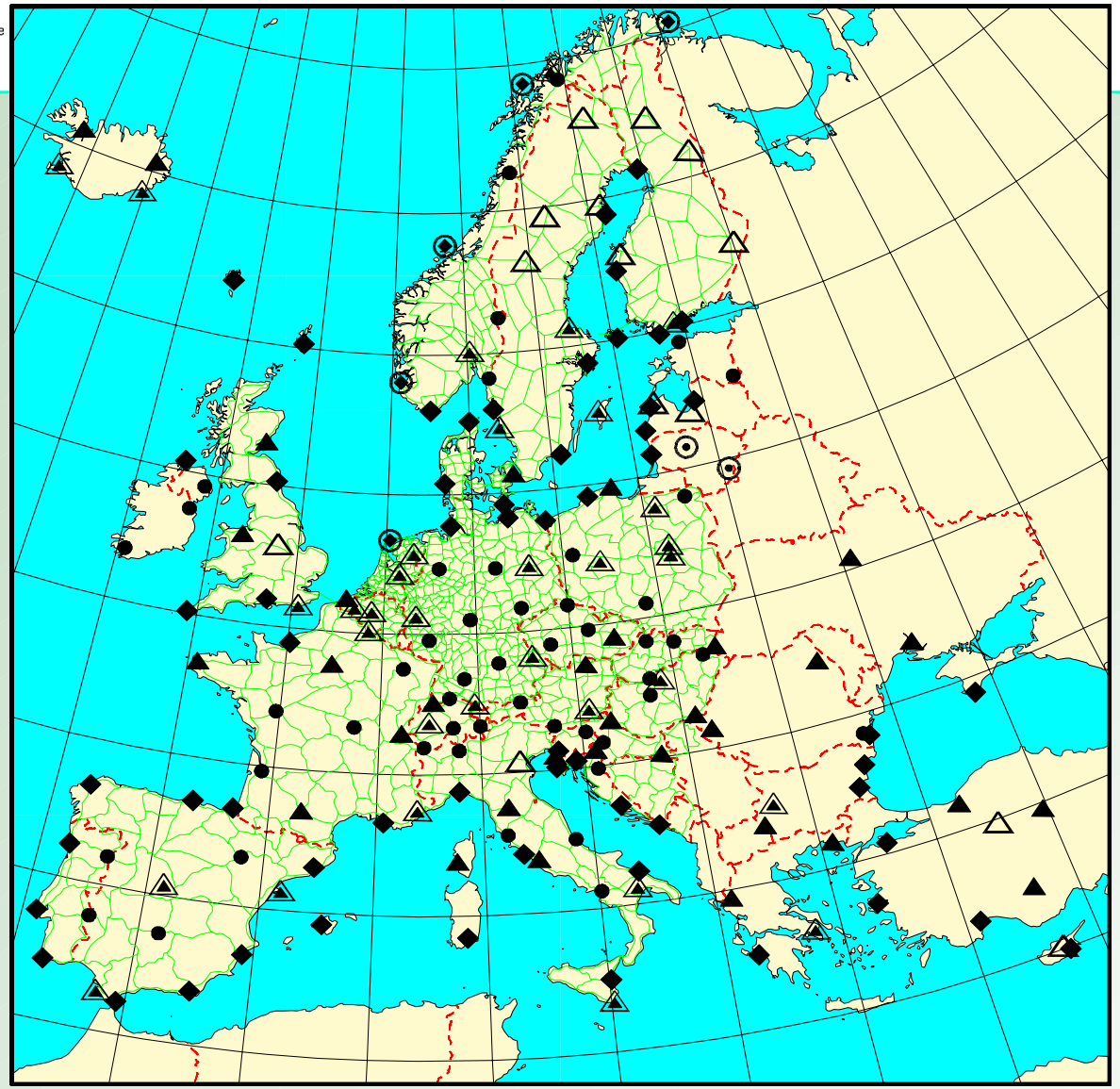
$$g_i(t_k) + \varepsilon_{git} = g_{i,ref} + \Delta t_k \cdot v_{gi} = g_{i,ref} + \Delta t_k \cdot k \cdot v_{Hi}$$

- tide gauge / permanent

$$v_{TGi} + \varepsilon_{vTGi} = v_{TGi} \quad \text{with the convention } v_{TGi} = v_{hi} = v_{Hi}$$

- Altimetry

- Global gravity model (GGM)

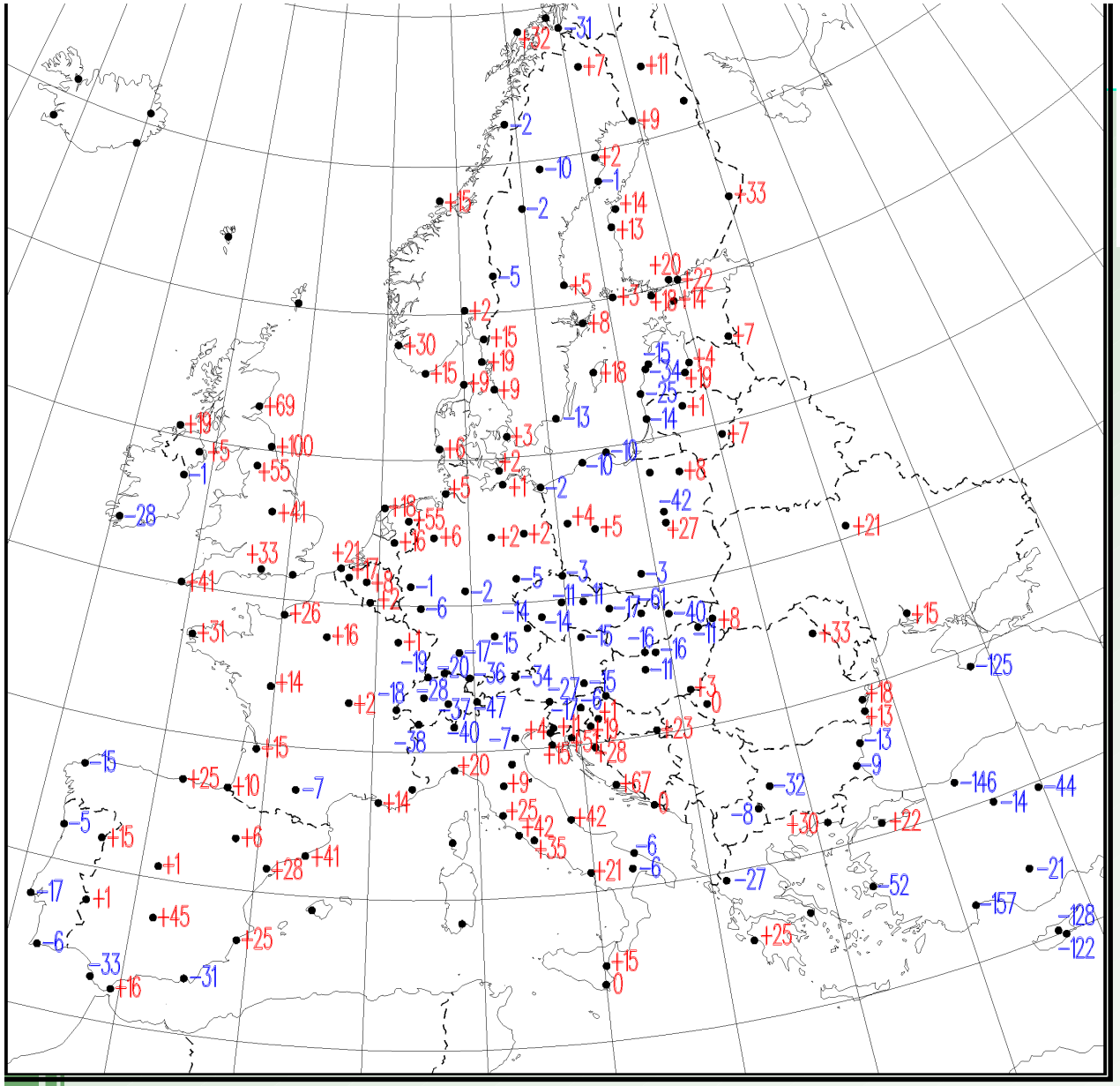


EUVN

European Vertical Reference Network

1997.5

- ▲ EUREF sites
- ◬ GPS permanent stations - EUREF
- △ GPS permanent stations
- ● UELN & UPLN nodal points
- ⊙ GPS permanent stations - nodal points
- ◆ Tide gauge sites
- ◉ GPS permanent stations - tide gauge
- UELN lines



EUREF´s EUVN project (2001)

200 GPS/levelling points

Differences between gravimetric height components and GPS heights ($\zeta_{EGG97} + H_{EUVN}$) - h_{ITRS}

Relations between ITRS and EVRS/WHS - 1 -

(conventions, parameters, realization)

ITRS	WHS/EVRS
IUGG Resolution No. 2, Vienna 1991	IAG Subcommission for Europe, Resolution No. 5, Tromsö 2000

origin

Explicit	Geocentric, the center of mass being defined or the whole Earth, including oceans and atmosphere. (At present no convention related to the motion of the geocentre)	Implicit

orientation

Initial BIH orientation. Non-rotating system. No global residual rotation with respect to horizontal motions at the Earth´s surface.	No necessary convention

units-scale

SI unit meter The ITRS scale consistent with the Geocentric Coordinate Time (TCG)	SI units meter and seconds $W_o=U_o$ The scale of the Earth body W_o is approximated by the normal potential of the mean Earth ellipsoid U_o which includes the masses of the oceans and the atmosphere.

Relations between ITRS and EVRS/WHS - 2 -

ITRS	WHS/EVRS
	coordinates
quasi – Cartesian system X	potential of the Earth gravity field $W_p = W(X)$ $= U_p + T_p$ (GPM) $= W_o - C_p$ (Levelling)
	system parameters
	mean Earth ellipsoid (U_o, GM, J_2, w)
	realization
ITRF 2000 tide-free	EVRF 2000 (UELN 95/98, ETRS89) $W_p = W_{NAP} + C_p$ (Levelling) zero tidal system (?) GRS 80

Height Components and Tidal Systems

	gravity g/Δg	geoid W/N	levelling height ΔH	altimetry h	mean sea level msl	position X/h
Mean tidal system **Mean/zero crust** (Stokes is not valid if masses outsite the Earth surface)	Δg_m	N_m	ΔH_m	**Relation to N_m for oceanographic studies**	h_{msl}	
Zero tidal system **Mean/zero crust** (Recommended by IAG Res. No. 16, 1983)	Δg_z	$\xrightarrow{\text{Stokes}} N_z$ **(EGG97)**	ΔH_z c_p			
Tide-free system **Tide-free crust** (unobservable, far away from the real earth shape – there is no reason for the non tidal/tide free concept)	Δg_n	$\xrightarrow{\text{Stokes}} N_n$ **(EGM96)**				X_n **ITRFxx, ETRS89**

(3) The European Vertical Reference Frame EVRF2000

The EVRS is defined as a world height system (WHS).

The EVRS is realized by

- **the geopotential numbers and normal heights of nodal points of the United European Levelling Network 95/98 (UELN 95/98)**
- **extended for Estonia, Latvia, Lithuania and Romania**
- **in relation to the Normaal Amsterdams Peils (NAP).**

Conventions for EVRS Datum Definition

From 2000 WHS

The European Vertical Reference System (EVRS) is a gravity-related 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 $-\Delta W_P$ 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 system[1], in agreement with the IAG Resolutions No 16 adopted in Hamburg in 1983**

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.

datum

geocentric, including oceans and atmosphere

W_0 independend from the tidal system

coordinate system

SI units
$m^2 \cdot s^{-2}$

$W_p = U_p + T_p$ (BVP)
$W_p = W_0 - c_p$ (levelling)

$$H_n = \frac{c_p}{\bar{\gamma}}$$

frame

EVRS Realization (EVRF 2000)

EVRF 2000 *Datum*

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 $m^2\ s^{-2}$ and the equivalent normal height 0.71599 m of the reference point of the UELN No. 000A2530/13600.**

Realization of the EVRS 2000 datum

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 and the equivalent normal height of the reference point of the UELN No. 000A2530/13600.

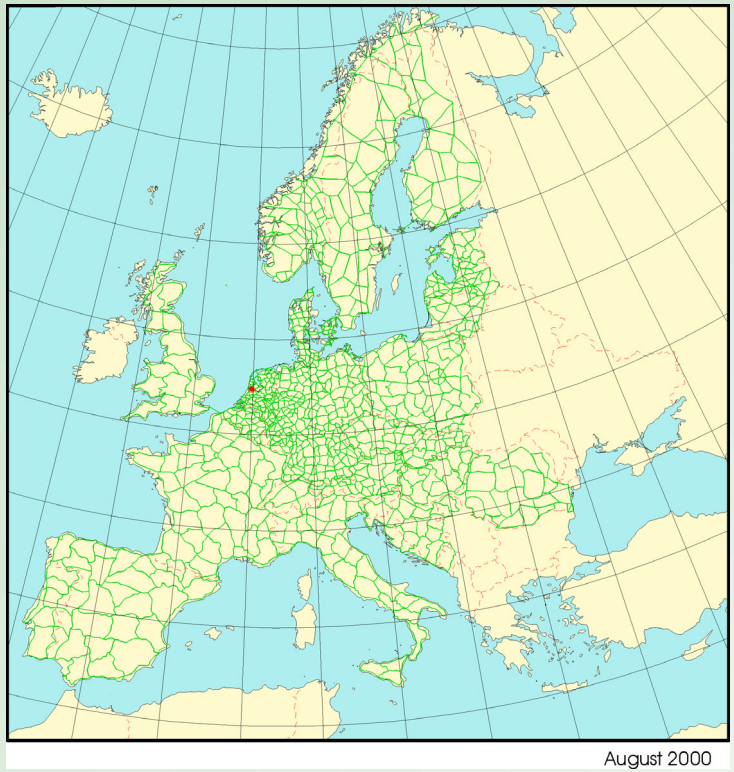
Table 1 Height of the fundamental EVRS2000 station and related information

Stationname Country	UELN number	Position in ETRS89	Height in UELN95/98		Gravity in IGSN71
		ellipsoidal latitude ellipsoidal longitude	geopotential number	normal height	
		in ° ' "	in $m^2 \cdot s^{-2}$	in m	in $m \cdot s^{-2}$
Reference point of EVRS 000A2530 The Netherlands	**13600**	52° 22' 53" 4° 54' 34"	**7.0259**	**0.71599**	9.81277935

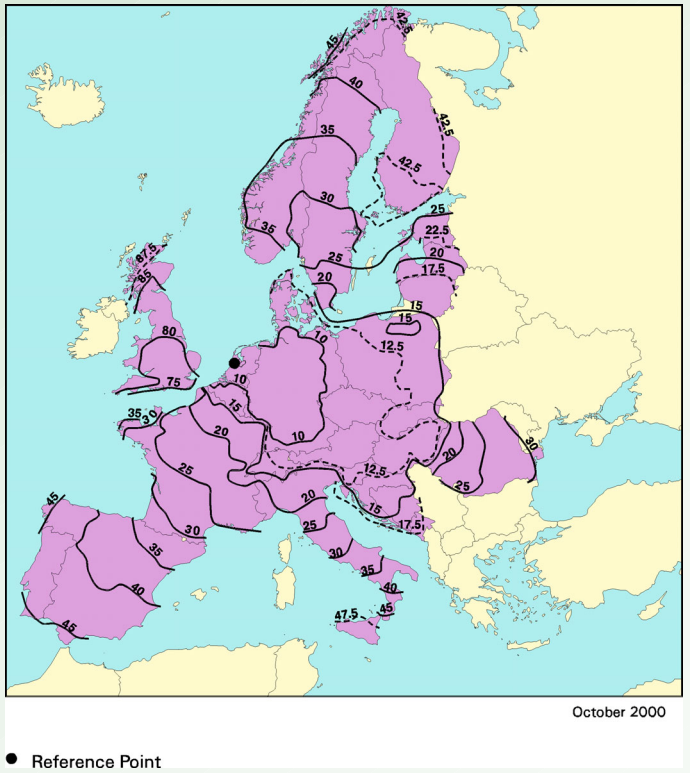
EVRF 2000 Frame

Unconstrained adjustment of geopotential numbers in relation to the reference point of UELN-73 (in NAP).

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)

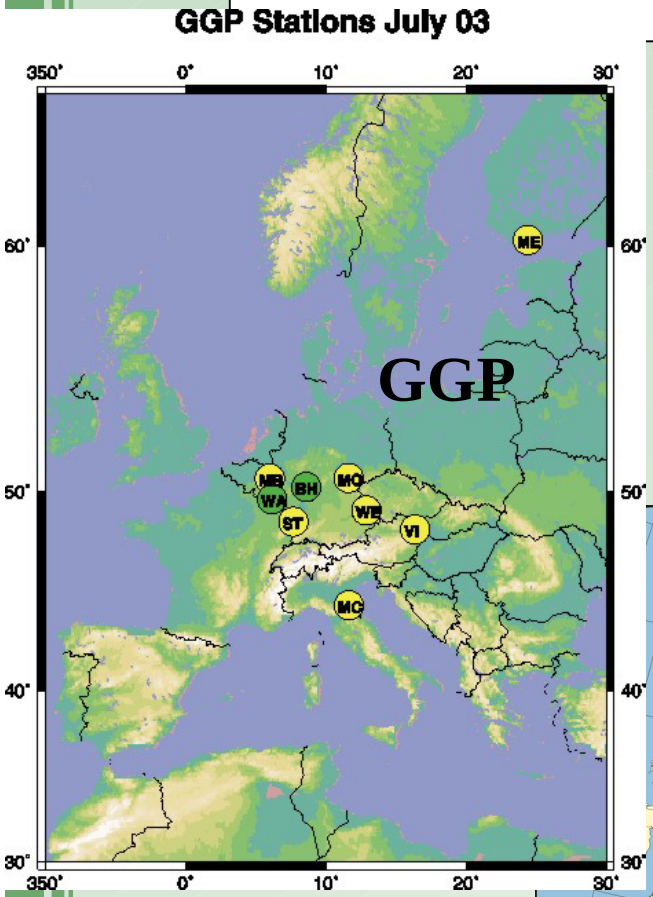


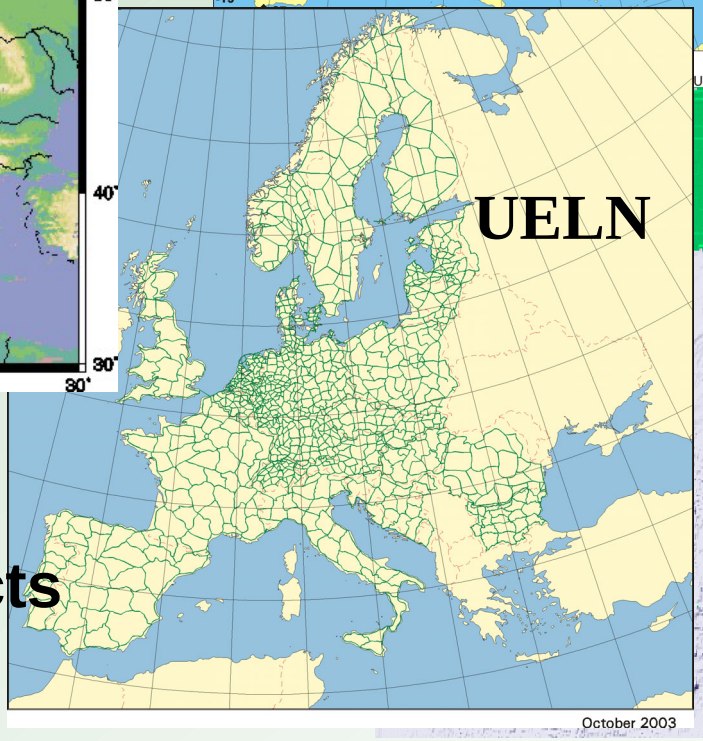
UELN 95/98 – Isolines of Precision [kgal · mm]

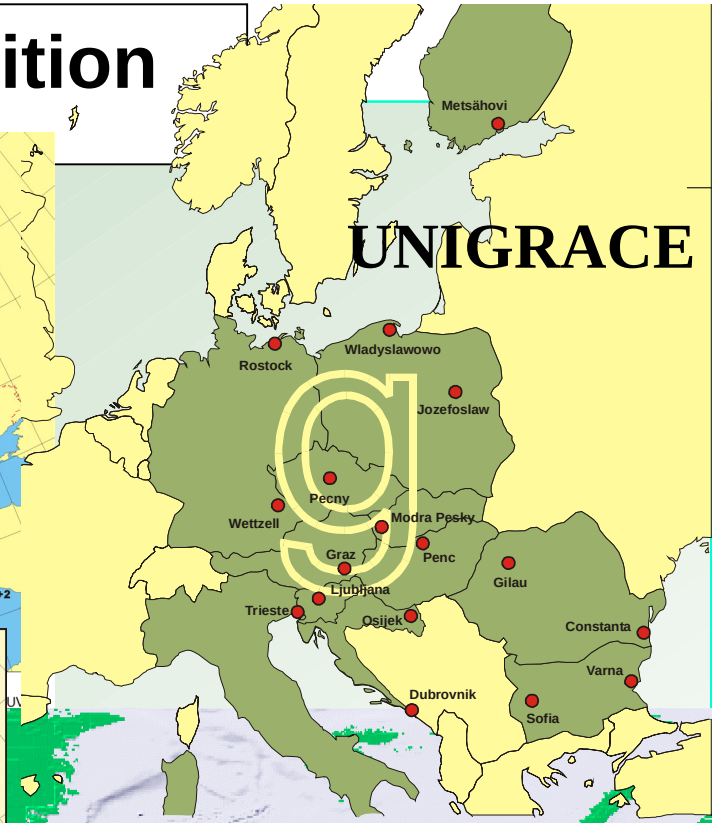
(4) European Combined Geodetic Network (ECGN)

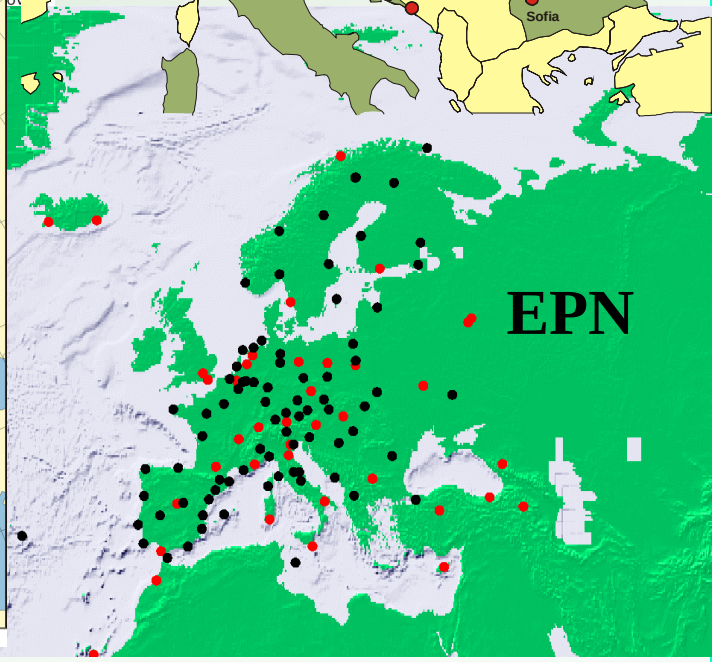
- **GGOS, NGOS**
- **Observation system**
- **Time series and periodic observations**
- **Combination of space geodesy and gravity at terrestrial reference stations (local ties)**
- **Using of available infrastructure, data bases and standards as far as possible**
- **Stepwise realization:**
  - **1st Call: Network infrastructure**
  - **2nd Call: Data processing, combination**
- **Level of combination:**
  - **I. at the stations**
  - **II. in the network**
  - **III. with external observations (e.g. GRACE)**

Motivation – Starting Position









European Projects

ECGN

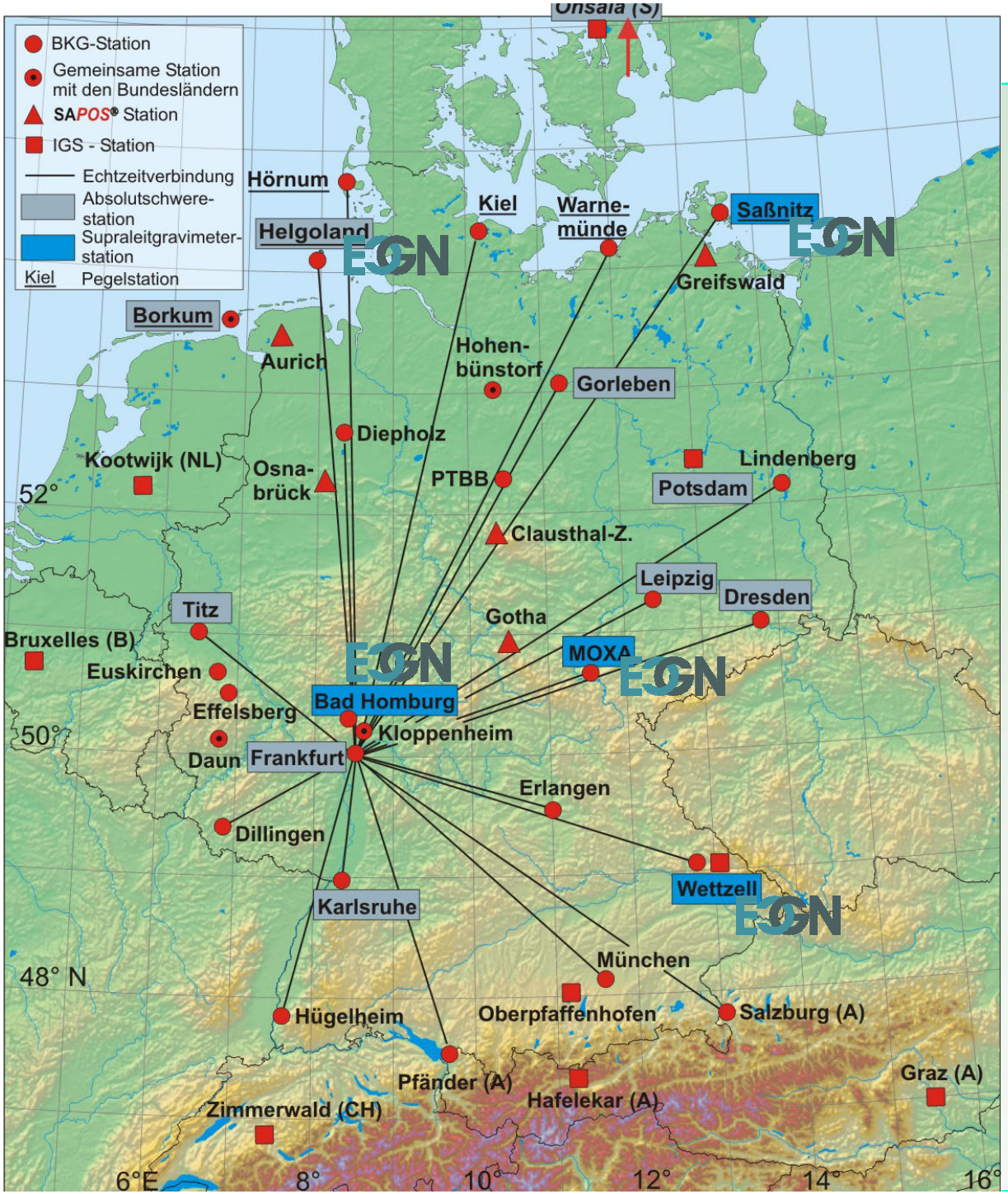
- 21 countries
- 74 stations with

- GPS (EPN)
- absolut gravity
- levelling to EVRS
- 6 super coducting grav.
- 15 tide gauges

- 8 ECGN core
- 42 ECGN
- 7 candidate
- 15 proposed

Status and Techniques (Standard: GPS, absolute gravity, levelling)

core station		super conducting gravimeter	
station		tide gauge	
candidate station			
proposed station			



EGN Germany

Wettzell (core)

Helgoland

Saßnitz

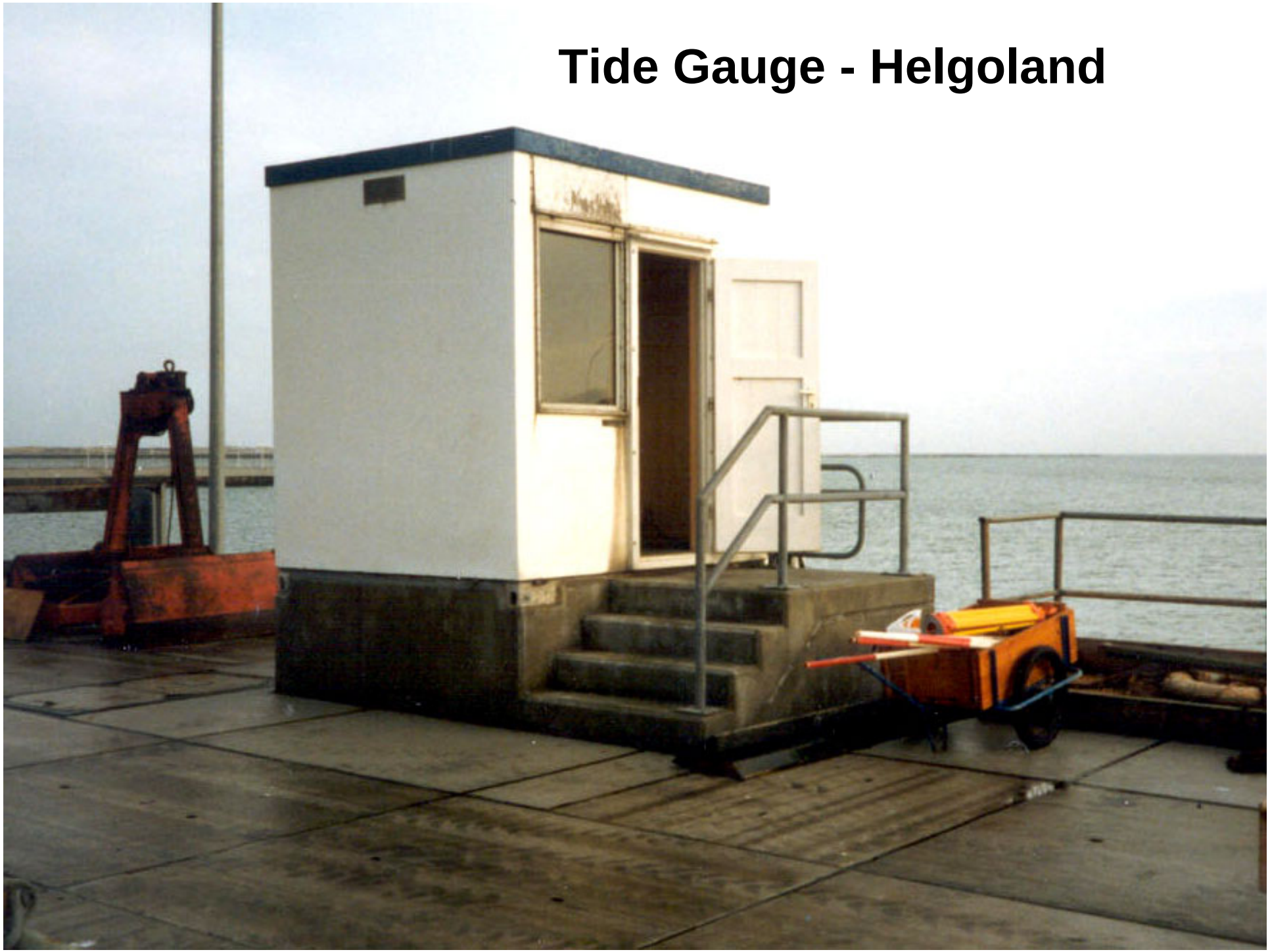
Moxa (candidate)

Bad Homburg (candidate)

GPS Antenna - Helgoland

Absolut Gravimeter Measurements - Helgoland

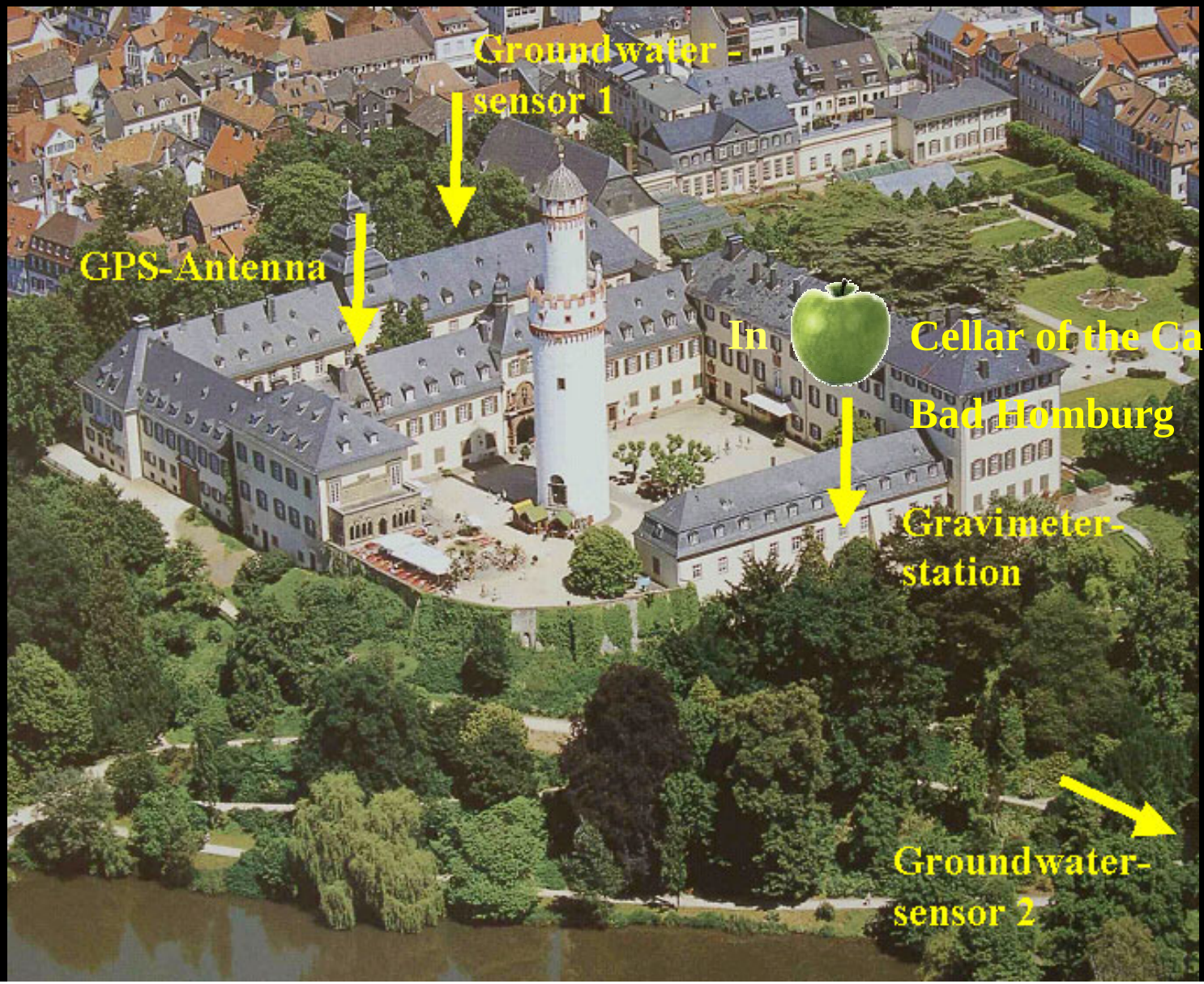
Tide Gauge - Helgoland



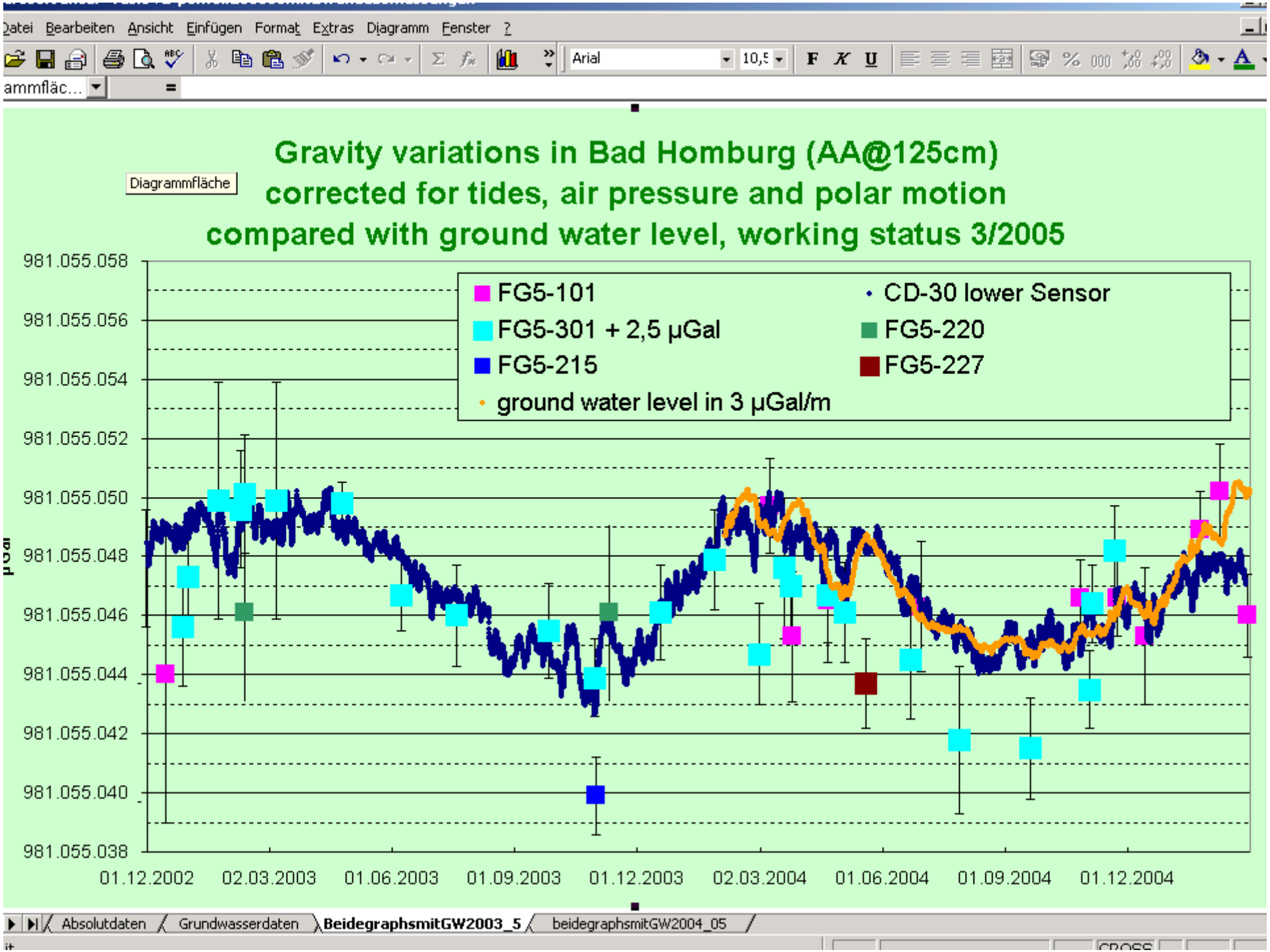
Bundesamt für Kartographie und Geodäsie

Control Network - Helgoland

Gravimeter Station Bad Homburg



Bad Homburg gravimetric observatory, pillar BA with A10 #002 and pillar AA with FG5-101


Datei Bearbeiten Ansicht Einfügen Format Extras Diagramm Fenster ?
Arial
10,5
Diagrammfläche
Gravity variations in Bad Homburg (AA@125cm)
corrected for tides, air pressure and polar motion
compared with ground water level, working status 3/2005
FG5-101
FG5-301 + 2,5 µGal
FG5-215
CD-30 lower Sensor
FG5-220
FG5-227
ground water level in 3 µGal/m
µGal
981.055.058
981.055.056
981.055.054
981.055.052
981.055.050
981.055.048
981.055.046
981.055.044
981.055.042
981.055.040
981.055.038
01.12.2002
02.03.2003
01.06.2003
01.09.2003
01.12.2003
02.03.2004
01.06.2004
01.09.2004
01.12.2004
Absolutdaten
Grundwasserdaten
BeidegraphsmitGW2003_5
beidegraphsmitGW2004_05

ECGN Stations

Status:2005-03-24
Status of Proposals: 2004-09-29, # Countries: 21, # Stations: 74

http://www.bkg.bund.de/ecgn

Country	Site Name	Station Code (GPS)	GPS Status (EPN)	absolute gravity measurement	Super conducting gravimeter (SG)	Levelling	Tide Gauge	EUVN point (close to ECGN point)	SLR	VLBI	Meterology	other Technologies	Comment	Status	Meta data form
		[.] code not available, temporary defined code	(p) = planned			1=UELN 2=national network							necessary supplements/ arrangements	core ok c = candidate p = proposed	
AT	Graz	GRAZ	EPN	1998, 2001		1	no	GRAZ	permanent		yes	SLR		ok	yes
AT	Hafelekar	HFLK	perm (IGS)	2003, 2004	no	not possible	no	no	no	no			EPN	ok	
AT	Pfaender, Moos, Bregenz	PFAN	EPN	1988 Bregenz, 2004	no	1	no	PFAN	no	no				ok	yes
AT	Trafelberg	[TRAF]	perm	2003	planed for 2004	planned	no	no	no	no	yes	seismometer	EPN, UELN	ok	yes
AT															
BG	Rojen	[ROJE]	perm (p)	planed			no	no						p	
BG	Sofia	SOFI	EPN	1998, 2001 form UNIGRAC		2	no	BG03					eccentricity, UELN	ok	
BG	Varna	[VARN]	perm (p)	UNIGRACE Station		2	yes	BG04						p	
BG															
CH	Zimmerwald L+T 88	ZIMM	EPN	1997, 2004, time series planed		1	no	ZIMM	permanent		yes	Earth tide gravimeter, astro measurements (zenith camera), astronomic project CQSSP - link to astron. reference system), meas. of high-frequency gravity variations		core	yes
CH															
CZ	Pecny, Ondrejov, Geodetic Observatory	GOPE	EPN	time series since 1978, now own FG5		1	no	GOPE			yes	relative gravity measurements, tidal gravity variations		core	
CZ															
DE	Bad Homburg	[HOMB]	perm (p)	time series	since 1983		no	no						p	yes
DE	Helgoland Island	HELG	EPN	1997, 2001, 2003	no	2 1 - planed	yes (since 1924)	no	no	no				ok	yes
DE	Moxa	MOXA	perm	2001, Nov. 2002, May 2003	yes	planed	no	no	no	no	yes		EPN, UELN	ok	yes
DE	Sassnitz	SASS	EPN	May 2003	planed	2	yes (since 1882)	no	no	no	yes		UELN	ok	yes
DE	Wettzell	WTZR	EPN	twice a year	yes	1	no	WTZR	permanent since 1988	permanent since 1983	yes			core	yes
DE															

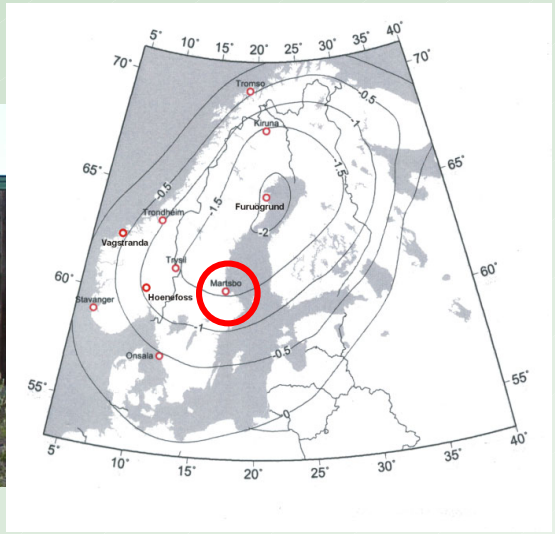
Standards and Guidelines

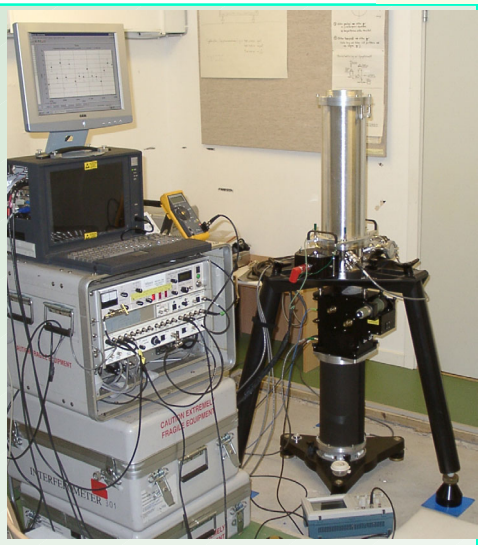
GPS, gravity measurements, levelling, tide gauge

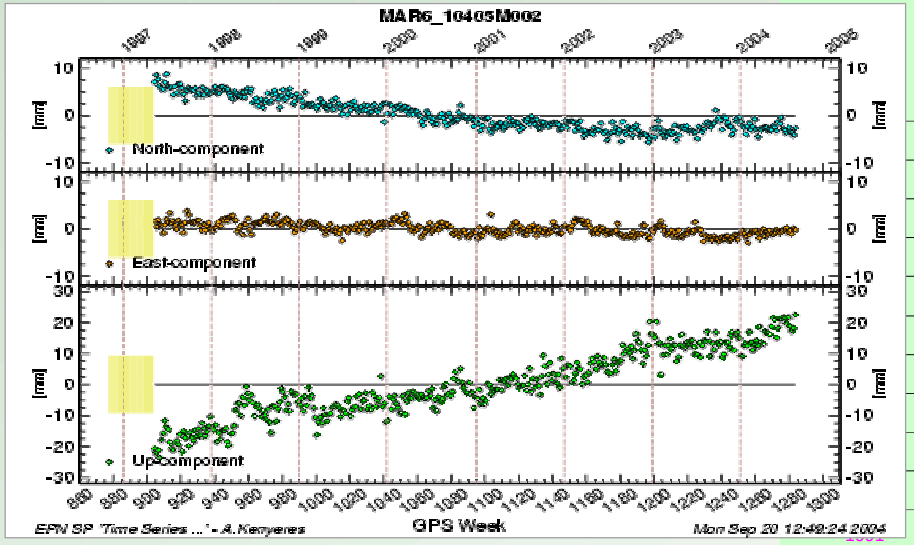
- **GPS**
  - All ECGN stations shall be included to the European Permanent GPS network (EPN) see: http://www.epncb.oma.be
- **Gravity measurements**
  - ECGN Standards for absolute gravity measurements (see ECGN Website – PDF File)
  - Standard for SG observations - Global Geodynamic Project GGP see: http://www.eas.slu.edu/GGP/ggpas.html

- **Levelling**
  - All ECGN stations shall be connected to the United European Levelling Network - UELN (see http://evrs.leipzig.ifag.de)
- **Tide Gauges**
  - For Tide Gauge measurement the data of Permanent Sea Level Observing System (PSMSL) (http://www.pol.ac.uk/psmsl/datainfo/contrib.html) and the project European Sea Level Service (ESEAS) shall be used
- **Local Ties**
  - Each type of observation has its own marker and one marker has to be declared as main marker
  - ECGN Standard for Local Ties Determination (see ECGN Website – PDF File)
- **Meta Data Base**
  - ECGN Meta Data Form (see ECGN Website – PDF/TXT File)

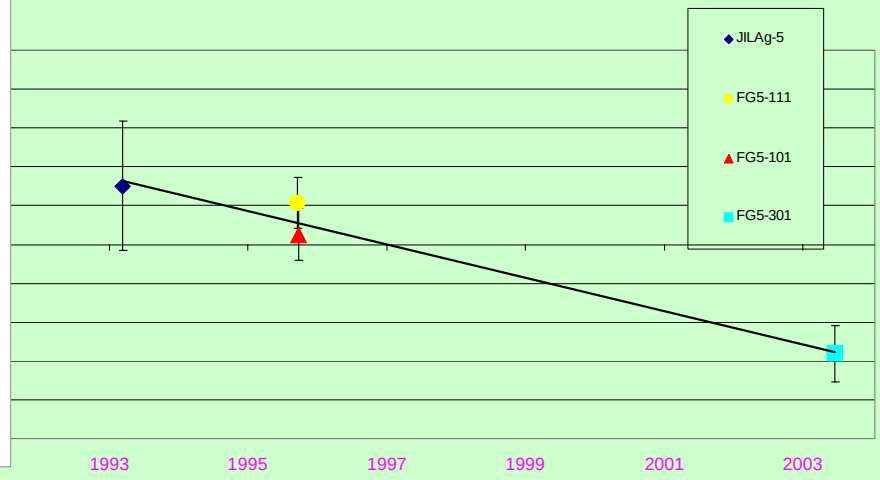
Kombination Schwere – Höhe Martsbo (Sweden)







Mårtsbo (S),
observed gravity changes
g_{mean}@125 cm = 981 923 082,4 µGal (gradient$_{mean}$ = 287,5 µGal/m)



GPS-Beobachtungsreihe
EPN (EUREF Permanent Network)

-1,29 µGal / year ± 0,3 µGal / year

Recommendations for Gravity:

1. All ECGN FG5 owners are called to provide the meta data information of their measurements to ECGN, to store the 1st level and 2nd level data, and to provide the link.
2. The meta data information of the measurements shall hosted at ECGN home page.

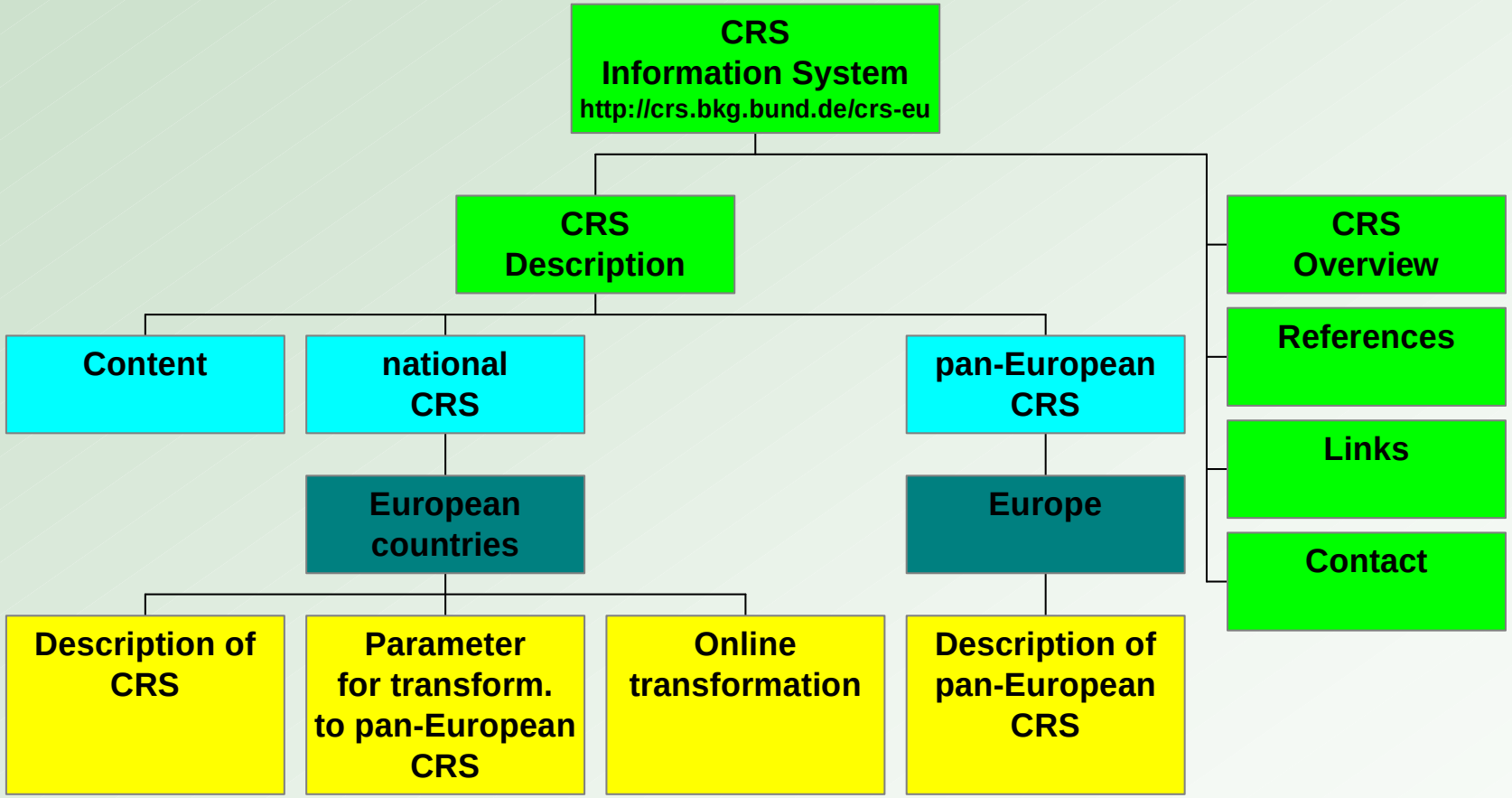
ECGN Web Site

- **ECGN Home Page Address: http://www.bkg.bund.de/ecgn**
- **ECGN Website *Guidelines and Forms* with links to guidelines and forms for the different observation techniques**

  Startpage - Guidelines

- **or Links from BKG-Website http://www.bkg.bund.de Rubriks Geodesy or Information Services**

(5) The Information System for European Coordinate Reference Systems (CRS)



CRS-EU Web-Address

- **Available at web-address**

  http://crs.bkg.bund.de/crs-eu

- **Former existing address**

  http://crs.ifag.de

  will be forwarded to the new address for some time via an information website.

Available Information for European Countries (1)

Country	Country_ID	Height	
		CRS-Description	Transformation to EVRF2000
Albania	AL		
Austria	AT	**published**	**published**
Bosnia / Hercegovina	BA	**existing data**	**existing data**
Belgium	BE	**published**	**published**
Bulgaria	BG	**published**	**published**
Switzerland	CH	**published**	**published**
Cyprus	CY		
Czech Republic	CZ	**existing data**	**existing data**
Germany	DE	**published**	**published**
Denmark	DK	**published**	**published**
Estonia	EE	**published**	**published**
Spain	ES	**published**	**published**
Finland	FI	**published**	**published**
France	FR	**published**	**published**
Great Britain	GB	**published**	**published**
Gibraltar	GI		
Greece	GR	**existing data**	*no UELN*
Croatia	HR	**existing data**	**existing data**
Hungary	HU	**published**	**published**

Available Information for European Countries (2)

Country	Country_ID	Height	
		CRS-Description	Transformation to EVRF2000
Ireland	IE	**published**	*no UELN*
Iceland	IS	no levelling network	
Italy	IT	**existing data**	**existing data**
Lithuania	LT	**published**	**published**
Luxembourg	LU	**published**	*no UELN*
Latvia	LV	**existing data**	**existing data**
Macedonia	MK		
Malta	MT		
Northern Ireland	NI	**existing data**	*no UELN*
Netherlands	NL	**published**	**published**
Norway	NO	**published**	**published**
Poland	PL	**existing data**	**existing data**
Portugal	PT	**published**	**published**
Romania	RO	**existing data**	**existing data**
Russia	RU	**existing data**	*no UELN*
Sweden	SE	**published**	**existing data**
Slovenia	SI	**published**	**published**
Slovak Republic	SK	**published**	**published**
Turkey	TR	**published**	*no UELN*
Ukraine	UA	**existing data**	*no UELN*

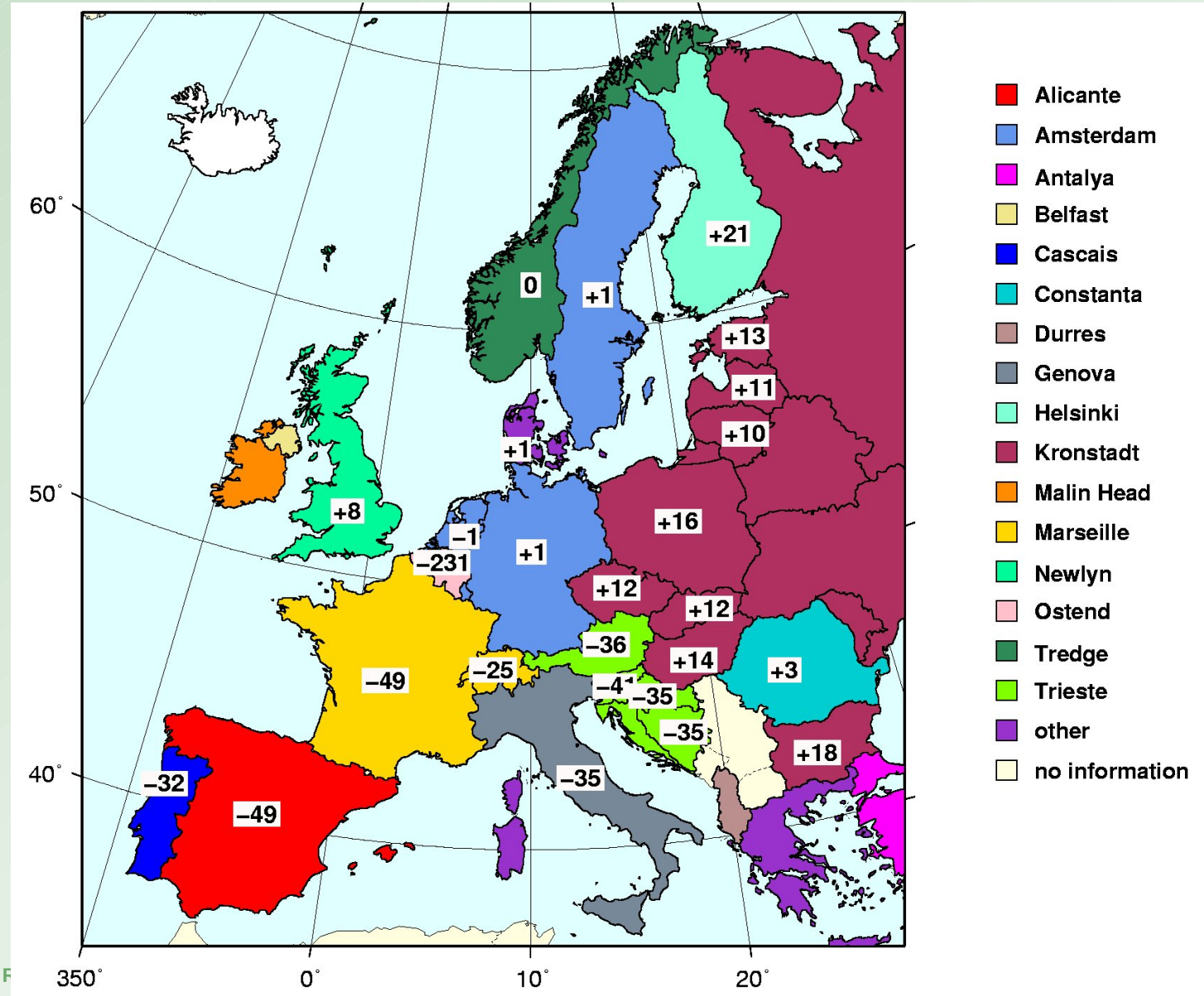
Available transformation parameters for height

Country	Verification by the country	identical points	Parameters			RMS	residual deviations	
		number + kind	translation in cm	incl. in latitude in cm / 100km	incl. in longitude in cm / 100km	in cm	min in cm	max in cm
AT	x	114 UELN	- 35.6	- 2.8	- 2.8	3.1	-6.1	+6.1
BA/HR		40 UELN	- 34.5	- 0.3	- 0.9	0.7	-1.0	+1.4
BE	x	4 EUVN	- 231.1	- 0.8		0.2	-0.2	+0.2
BG	x	36 UELN	+ 18.2	+ 0.1	- 0.2	0.2	-0.6	+0.4
CH (LN02)	x	225 UELN	- 24.5	- 10.2	- 1.6	3.3	-8.6	+9.4
CZ		53 UELN	+ 11.6	+ 1.7		1.4	-3.5	+2.8
DE (DHHN92)	x	443 UELN	+ 1.4	- 0.1		0.2	-0.7	+0.6
DK	x	707 UELN	+ 1.1	+ 0.1	+ 0.5	0.3	-0.9	+0.8
EE	x	36 UELN	+ 13.3	- 0.7	+ 0.2	0.3	-0.5	+0.5
ES	x	70 UELN	- 48.6	- 0.2	+ 0.3	1.0	?	?
FI		66 UELN	+ 21.3			0.3	-0.7	+0.9
FR	x	8 EUVN	- 48.6			0.5	-0.4	+1.0
GB	x	5 EUVN	+ 8.1	- 2.7	- 1.1	1.9	-1.2	+2.2
HR		40 UELN	- 34.5	- 0.3	- 0.9	0.7	-1.0	+1.4
HU	x	35 UELN	+ 14.0	+ 0.4	- 0.1	0.3	-0.7	+0.6
IT		9 EUVN	- 35.3	+ 0.2	+ 0.3	0.7	-0.6	+1.1
LT	x	46 UELN	+ 10.2		+ 0.1	0.2	-0.2	+0.3
LV		123 UELN	+ 10.5		+ 0.2	0.7	-2.0	+2.2
NL	x	757 UELN	- 0.5			0.2	-2.1	+0.4
NO	x	117 UELN	- 0.1	- 0.5	+ 1.7	3.7	-7.6	+7.0
PL		98 UELN	+ 16.0	+ 0.5		0.5	-2.0	+0.9
PT	x	5 EUVN	- 31.5			1.3	-1.4	+2.1
RO		46 UELN	+ 2.8	+ 0.1	+ 0.1	0.2	-0.5	+0.9
SE		21 EUVN+Tide G	+ 1.0	- 0.6		1.1	-2.3	+2.0
SI	x	9 UELN	- 41.1	- 1.6	+ 0.4	0.3	-0.4	+0.4
SK		3 EUVN	+ 12.2	+ 1.0		0.2	-0.1	+0.1

Bundesamt für Kartographie und Geodäsie

Reference Tide Gauges in Europe and

Transformation parameters to EVRF2000 in cm



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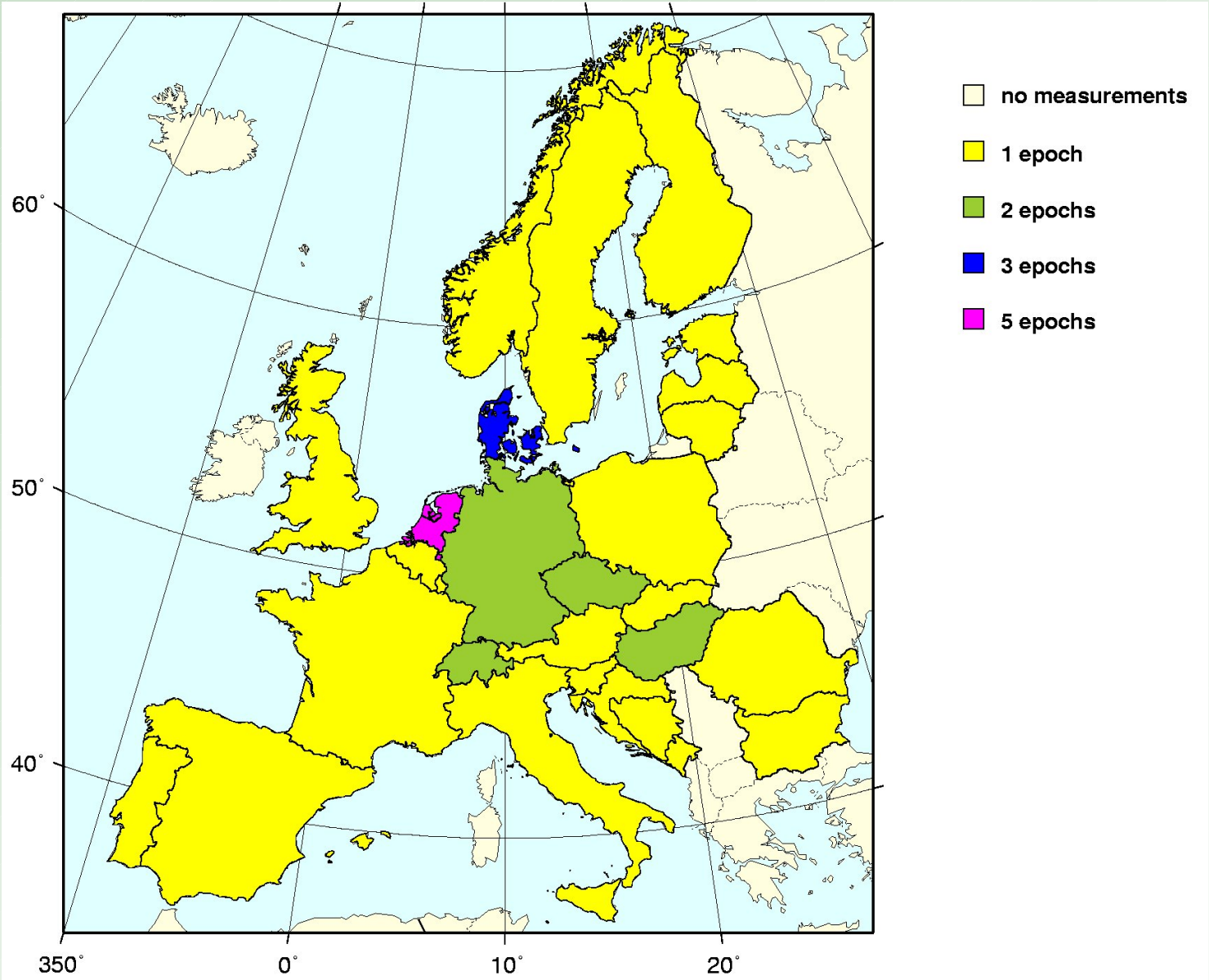
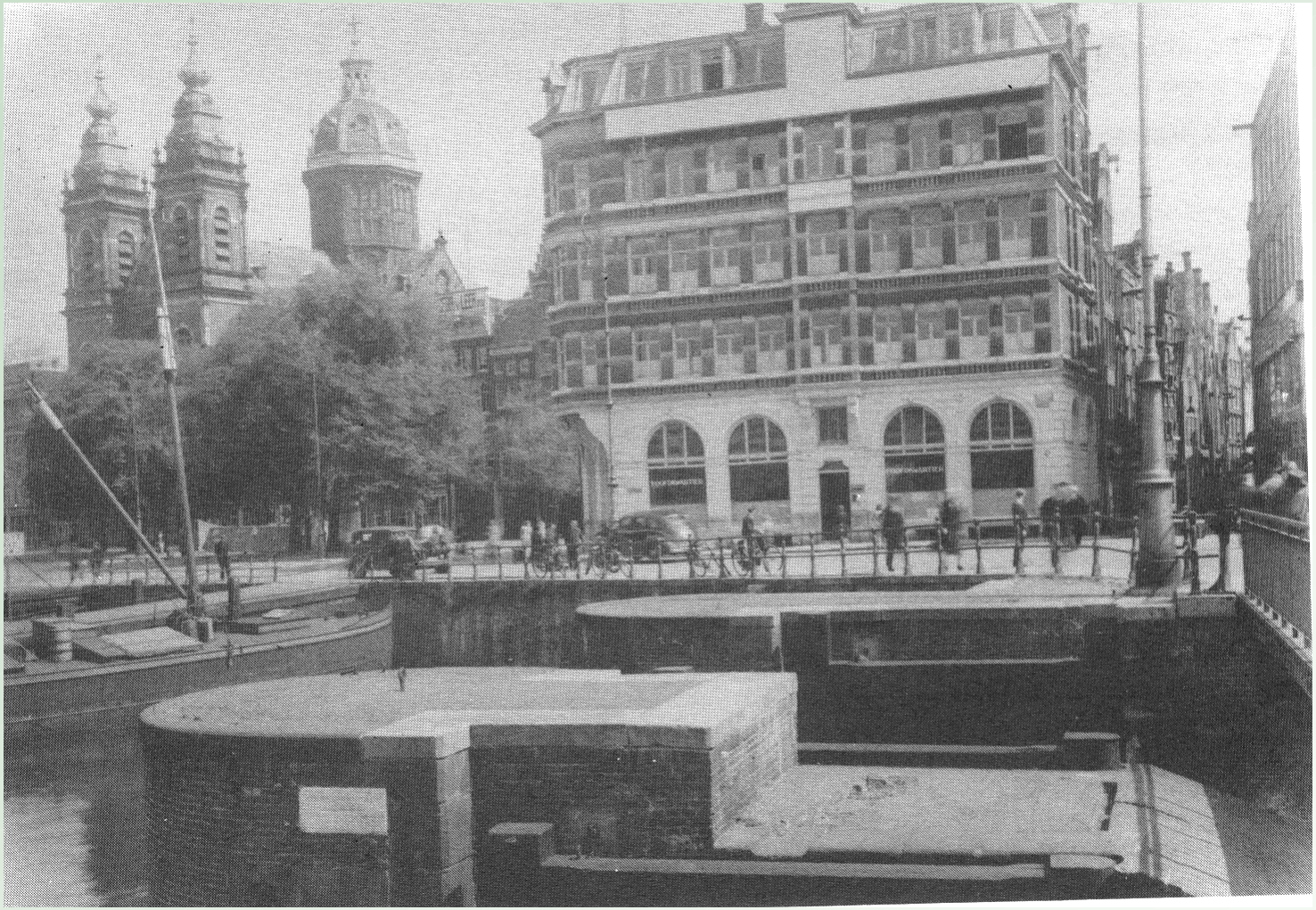
(6) EVRF/UELN2006 and the Relationship to the New Icelandic Vertical Reference

Motivation:

Request of the European Commission to define and realize EVRS for ESDI/INSPIRE

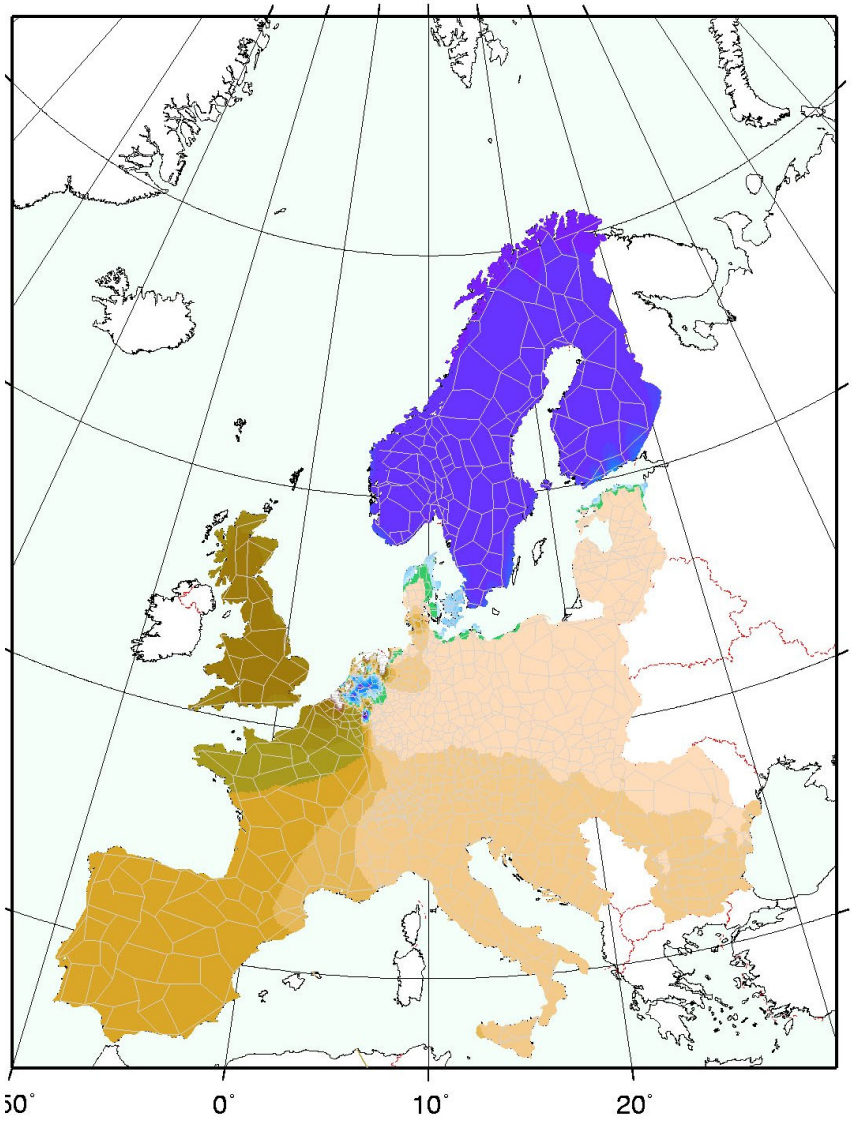
Numbers of Epochs in the UELN/EVRS Data Base (status May 2005)



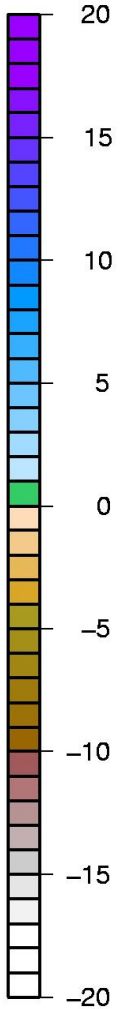


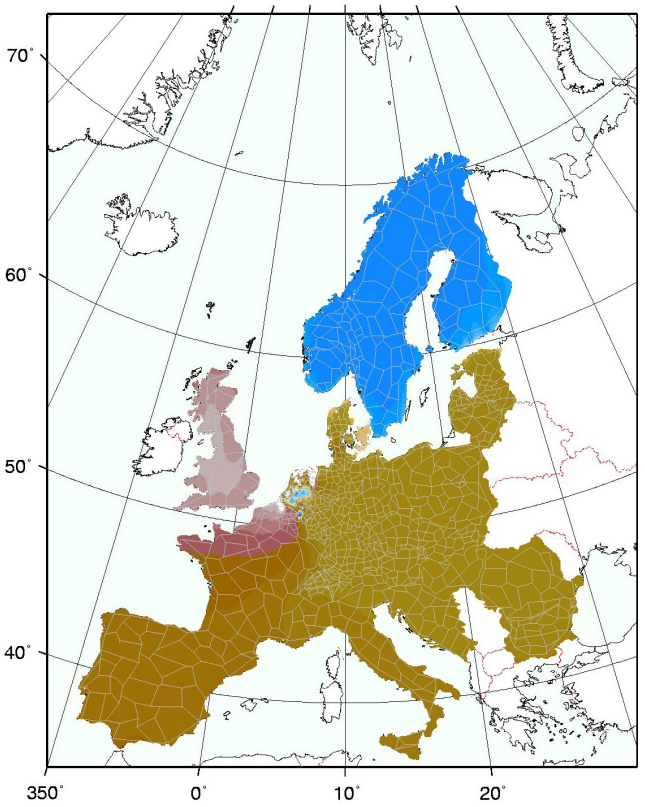
Letzter Original- „dykpeilsteen“ in der „Nieuwe Burg“-Schleuse

Differences between a new UELN adjustment with 23 datum points all over Europe of the UELN95/98 adjustment



Differences to the heights of the last adjustment version in kgal·mm





Differences between a new UELN adjustment with one datum point to UELN95/98.

EVRS 2006 datum realization

With several selected stable height fundamental points (in minimum 2 per participating countries)

Two ways:

$W_p = W_0 - c_p$ (levelling) *from a former UELN adjustment*

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

$W_p = U_p + T_p$ (BVP) *from a new GGM (IAG2005, or a combined CHAMP/GRACE model (CG01C) or the new EGM*

$$\zeta = \frac{T_p}{\gamma_Q} = \frac{W_P - U_P}{\gamma_Q}$$

and GPS heights h_p

$$H_n = h_P - \zeta$$

Height Datum

is the relation of the reference surface to the Earth body.

Definition:

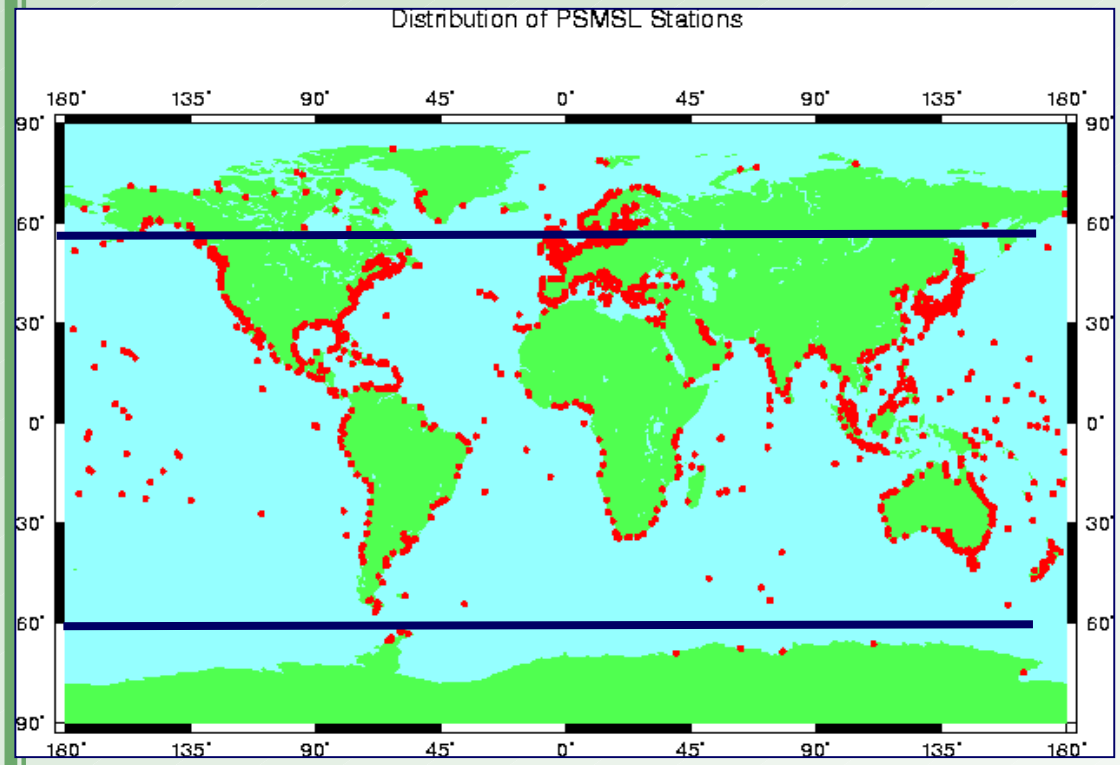
- **The level of the equipotential surface of a World Height System (WHS) is the mean sea surface – MSL**
- **The ellipsoid shall have the same scale – mean Earth ellipsoid (geocentric) - ME**
- ***Convention:*** $U_o^{ME} = W_o^{MSL}$

Mean Earth Ellipsoid (ME): $U_o^{ME}, GM^{ME}, f^{ME}, \omega^{ME}$

(W_0 is independend from tidal system, Bursa 1999)

Conventions for the Realization of MSL (Proposal)

- **Average of the heights of the free oceans**
  - **in an area from – 60° to + 60° latitude**
  - **in a time period of 18.6 years**
  - **to the epoch 2000.0**



using
- **satellite altimetry missions**

processed by
- **a future IAG altimetry service**

combined with
- **PSMSL tide gauges**
- **GPS obs. (IGS TIGA-PP)**
- **the best global gravity model (GRACE, ...)**

EVRS 2006 frame (realization by levelling)

- Readjustment of UELN as free network
- Use of all new measurements (i.e. Scandinavia)
- Reduce the data to a common epoch (the counties are asked to provide repeated levellings)
- Reduce the data to zero tidal system (UELN data and analysis centre)
- Close the Baltic ring (ask Russia for data)
- Connect the ECGN stations (by station owners)

Recommendations for EVRS 2006 in short:

1. The EVRS datum definition (conventions 2000) is fixed.
2. EVRS needs a new realization for the Datum.
3. A new EVRS realization of the frame is useful and needed.
4. Extended conventions for datum realization and frame are necessary.
5. For countries which are not part of UELN the fitted European geoid and ECGN stations can used to realize a common European Vertical Datum.

Recommendations for the New Icelandic Vertical Reference in short:

1. Adopt the EVRS conventions 2000 (WHS, Wp, zero tidal system).
2. Relate the datum of the Icelandic Vertical System to WHS by the best available geoid model, GPS and levelling observations in a number of points.
3. Include the Icelandic tide gauge stations for datum control – problem is to connect TG with altimetry.
4. In a first step realize the the frame by adjustment of levelling (geopotential numbers – normal heights?).
5. Use the best available parameter and the relationships to existing conventions.