Status of ECGN Project

Johannes Ihde, Trevor Baker, Carine Bruyninx, Olivier Francis, Martine Amalvict, Ambrus Kenyeres, Jaakko Makinen, Steve Shipman, Jaroslav Simek, Herbert Wilmes

EUREF Symposium 2005
Vienna, June 1-3

Contents

I. Objectives of ECGN

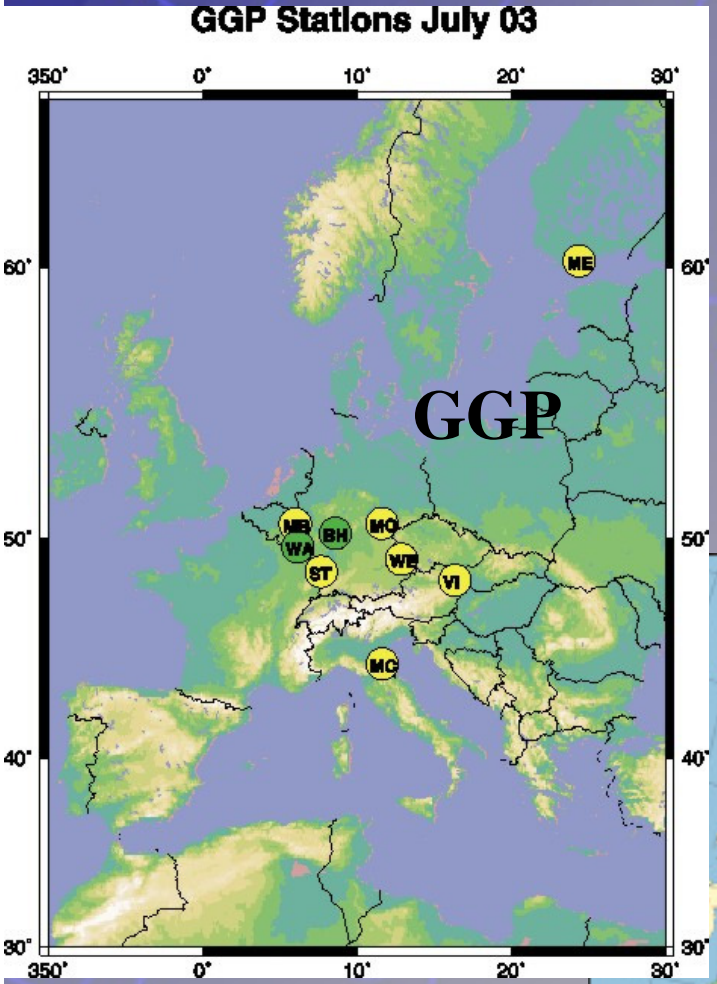
Realization of an integrated European Terrestrial Reference Frame for Spatial Reference and Gravity

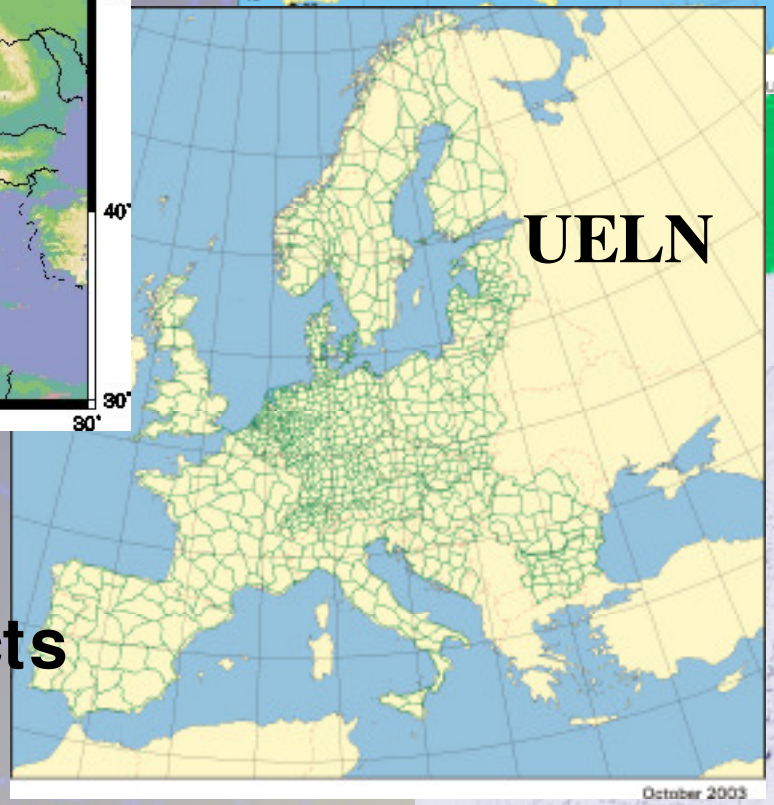
- Realization of a terrestrial reference system and maintenance of long time stability with an accuracy 10^{-9} for Europe especially in the vertical component (EVRS)
- In-situ combination of space geodesy (GPS) with Earth gravity parameters (gravity, heights)
- Modelling of influences of time depended parameters to TRF (of the solid Earth of the Earth gravity field, the atmosphere, the oceans, the hydrosphere)
- Modelling of terrestrial gravity field components to validate satellite gravity missions
- Geodetic platform in Europe for geo-initiatives (GMES, INSPIRE, GEOSS, GGOS)

Principles

- Observation system
- Time series and periodic observations
- Combination of space geodesy and gravity at terrestrial reference stations (local ties)
- Using of available infrastructure 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

II. News since EUREF Symposium 2004

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	✦		

ECGN Stations

Status:2005-03-24

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

Country	Site Name	Station Code (GPS)	GPS Status (EPN)	absolute gravitiy 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															

Station distribution:

Additional stations in

France (Montpellier, Grasse, La Rochell, Marseilles),
Hungary (Penc),
Luxembourg (Walferdange),
Poland,
Slovakia and
Iceland

are useful.

Standards and Guidelines

- For each main observation technique (GPS, gravity measurements, levelling, tide gauge) guidelines and forms for acquisition of data were prepared.
- Generally already existing data bases will be used for ECGN project.
- **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)

EPN Sites – ECGN Stationen

- All ECGN stations shall be included to the European Permanent GPS network (EPN), the stations have to fulfil the requirements of EPN.
- Standards for GPS EPN Stations (see EPN Central Bureau (see: http://www.epncb.oma.be)

Recomputation of the EPN network for investigations of secular height changes at the ECGN station is necessary.

Present Status, ECGN Meta Data Base

- **Meta Data**
  - In the meta data form the availability of the data and the access to the data shall be described
  - the local ties are also a part of the meta data form
  - ECGN Meta Data Form (see ECGN Website – PDF/TXT File)

Status of Meta Data Forms (1)

Country	ECGN points		Meta data form / Status report available
Austria	Graz Trafelberg	Haflekar Pfänder	yes (for 3 stations)
Bulgaria	Sofia Varna	Rojen	
Czech Republic	Geodetic Observatory Pency GOPE		
Denmark	Smidstrup Suldrup	Qaqortoq / Greenland	status report
Estonia	Suurupi		
Finland	Degerby Joensuu Metsähovi	Sodankylä Vaasa	
France	Strasbourg J9 Welschbruch (Vosges Mountains)	Brest	
Germany	Helgoland Moxa Sassnitz	Wettzell Bad Homburg	yes
Great Britain	Herstmonceux	Newlyn	yes
Italy	Bologona	Medicina	
Latvia	Riga	Irbene (candidate)	
Lithuania	Vilnius		
Moldavia	Balti (candidate) Comrat (candidate)	Chishinau (candidate)	
Netherlands	Tscherlling Ijmuiden	Westerbork	

Status of Meta Data Forms (2)

Country	ECGN points		Meta data form / Status report available
Norway	Bodø Ny-Alesund Stavanger Tromsø	Trondheim Trysil Vardø	
Poland	Borowa Gora		status report announced
Portugal	Gaia Lagos	Cascais	yes
Spain	A Coruña Albacete Alicante Almeria Caceres Ceuta *(Ebre)* Huelva La Palma La Rioja	*(Madrid)* Malaga Palma de Mallorca *(San Fernando)* Santander Sonseca Valencia Vigo Yebes *() points not quite clear*	
Sweden	Borås Kiruna Mårtsbo	Onsala Skellefteaa (Furuögrund) Visby	
Switzerland	Zimmerwald		yes

III. Gravity

A service, which supports

- the realization of absolute gravimeter measurements
- to store the absolute gravimeter data and
- the exchange of experiences on an international level

is still more or less missing.

ECGN project group see the need for

Coordination of Absolute Gravimeter Measurements

Realization of a Absolute Gravimeter Data Base

Gravity Measurements

- ECGN Standards for absolute gravity measurements (see ECGN Website – PDF File)
- For the absolute gravity measurements a own data base will be established
- Standard for SG observations - Global Geodynamic Project GGP (see: http://www.eas.slu.edu/GGP/ggpas.html)

Principles

The absolute gravimeter measurements should organized and financed on a national level by the owners of the instruments in cooperation eith station owners.

Measurements in countries with no absolute gravimeter instrument are organized in bilateral cooperation.

Absolute gravimeter instruments for ECGN measurements has to be compared to each other. It will be recommended to take part at the calibration campaigns ones per year in general, but at least ones in two years.

Owners of FG5 Gravimeter in Europe

In ECGN involved:
- Proudman Oceanographic Laboratory, Bidstone / Liverpool, UK
- Observatoire Royal de Belgique
- Ecole et observatoire des sciences de la terre (EOST) Strassbourg, France
- Instituto Geográfico Nacional, Madrid, Spain
- Vyzkumny Ustav Geodeticky, Topograficky a Kartograficky, Prague, Czech Republic
- EOST Luxembourg
- FGI Finland
- Bundesamt für Kartographie und Geodäsie

Not yet in ECGN involved:
- ASI, Matera, Italien
- Universität Hannover
- AUN, Norway

Standard authorities, not involved in field measurements:
- Swiss Federal Office of Metrology and Accreditation (METAS), Swiss
- National Physical Laboratory, Teddington, Middlesex, UK
- Bureau International des Poids et Mesures (BIPM), Sèvres, France

Owners of other absolute gravimeter:
- Bundesamt für Eich- und Vermessungswesen, Wien, Österreich

Absolute Gravimeter Data Base

The currently existing data bank at the Bureau Gravimetric International (BGI) do not fulfil the requirements of the project

ECGN WG has proposed standards for an absolute gravity data base in a decentralized ECGN data bank:

Each station owner and each instrument owner should provide the necessary information in a common format on its own web page.

Meta data will be available at the ECGN home page.

In three levels. (assumptions that all participating groups use measurements with the FG5 gravimeter and apply the producer-provided g-software)

1st level: *Raw data measurement files*. Every absolute gravity team store the own data according to an own database system.

2nd level: So-called *project files* and *set-files*.

P*roject file*: Every information related to the measurement station, instrument, actual measurement campaign and the data evaluation.

S*et-file*: Processing results as a time series of hourly least squares results with statistical information about the single drop dispersion, relevant applied corrections in the reprocessing.

3rd level: Gravity result of the complete station occupation at a certain epoch for a specified reference height with an error estimate, graphical representation, photos of the station outside and the instrument setup at the site to be able to detect occupation-specific influences upon the gravity determination.

Example File for Absolute Gravity Data – Observations –
"Project" Output File of g-Software

```
Micro-g Solutions g Processing Report
File Created: 06/22/03, 09:01:56

Project Name: HON_AC_301_210603a
g Acquisition Version:  1.0309
g Processing Version:  2.0807

Company/Institution:
Operator: Reinhold, Hoppe, Müller,Harsson

Station Data
Name: Honefos AC
Site Code: HON AC
Lat:  60.14600 Long:   10.24400 Elev:  113.00 m
Reference Height: 14.27 cm
Datum Height: 125.00 cm
Gradient:  -2.76 uGal/cm
Nominal Air Pressure:  999.75 mBar
Barometric Admittance Factor:  0.30
Polar Motion Coord:  0.069 "  0.539 "
Earth Tide (ETGTAB) Selected
Potential Filename: c:\gWavefiles\ETCPOT.dat
Delta Factor Filename: D:\gData\Hoenefoss AC\Honefoss.ini
Delta Factors
     Start    Stop      Amplitude     Phase Term
  0.000000  0.000147   1.00000    0.0000 M0S0
  0.000294  0.249951   1.18200   -0.2950 long
  0.721500  0.906315   1.14120   -0.1930 Q1
  0.921941  0.974188   1.14460    0.3190 O1
  0.989049  0.998028   1.15150    0.1950 P1
  0.999853  1.216397   1.13740    0.0980 K1
  1.719381  1.906462   1.16190    0.7370 N2
  1.923766  1.976926   1.16820    1.0510 M2
  1.991787  2.002885   1.16560    0.2760 S2
  2.003032  2.182843   1.16110   -0.3430 K2
  2.753244  3.937897   1.06760    0.0000 M3

Instrument Data
Meter Type: FG5
Meter S/N: 301
Factory Height: 116.35 cm
Rubidium Frequency:  10000000.00200 Hz
Laser: WEO (158)
ID: 632.99117754 nm (  0.19 V)
IE: 632.99119473 nm ( -0.16 V)
IF: 632.99121259 nm ( -0.45 V)
IG: 632.99123023 nm ( -0.74 V)
IH: 632.99136890 nm ( -1.61 V)
II: 632.99139822 nm ( -1.48 V)
IJ: 632.99142704 nm ( -1.40 V)
Modulation Frequency:  8333.420 Hz

Processing Results
Date: 06/22/03
Time: 03:19:29
DOY: 173
Year: 2003
Gravity:   981900638.52 uGal
Set Scatter:  8.63 uGal
```

Redundant information (?)

Complete information

```
Measurement Precision:  2.49 uGal
Total Uncertainty:  2.49 uGal
Number of Sets Collected:   12
Number of Sets Processed:   12
Set #s Processed: 1,2,3,4,5,6,7,8,9,10,11,12
Number of Sets NOT Processed:    0
Set #s NOT Processed:
Number of Drops/Set:  150
Total Drops Accepted:    1710
Total Drops Rejected:      90
Total Fringes Acquired:     700
Fringe Start:   30
Processed Fringes:    600
GuideCard Multiplex:    4
GuideCard Scale Factor:    250

Gravity Corrections
Earth Tide (ETGTAB): -48.51 uGal
Polar Motion:  0.46 uGal
Barometric Pressure: -1.25 uGal
Datum Height: 15.51 uGal
Reference Xo:  0.87 uGal

Uncertainties
Earth Tide:  0.00uGal
Ocean Load:  0.00uGal
Barometric:  0.00uGal
Polar Motion:  0.00uGal
Laser:  0.01uGal
Clock:  0.00uGal
System Type:  0.00uGal
Tidal Swell:  0.00uGal
Water Table:  0.00uGal
Unmodeled:  0.00uGal
System Setup:  0.00uGal
Gradient:  0.00uGal ( 0.00uGal/cm)
```

Standard assumptions for ECGN Project and station-dependent required

RSS for total error estimation

```
Comments

Achtung, es gibt außer Honefoss AA (gemessen 1993 und 1995) Gradient -2.362 bzw
- 2.393

Honefoss AB

Honefoss AC
AA liegt in

nicht mehr. Sehr guter Pfeiler AC im Statens Kartverk Keller.
Nochmals Neustart vor Ende des ersten Satzes. Grosse Streubreite.
```

General description of technical problems or station related environmental parameters

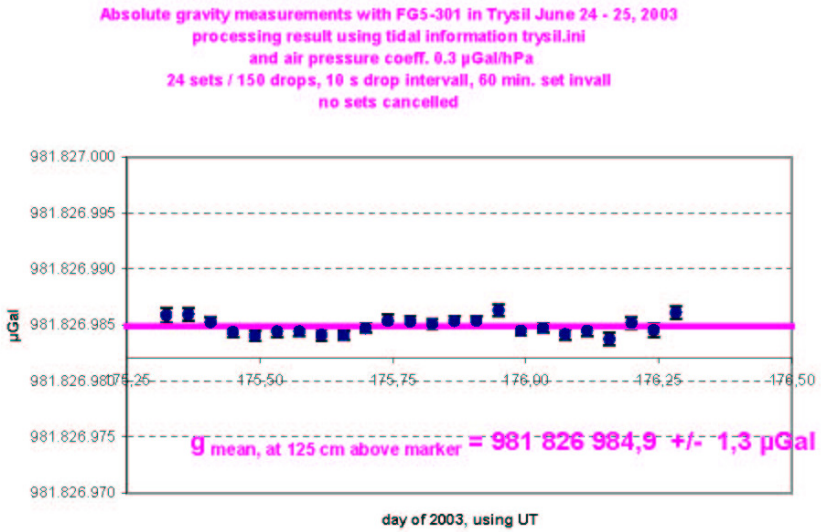
Additional useful information:

- measured ground water level
- reductions on eccentric occupations
- general documentation of measurements (seismic level, probable mass changes with respect to former measurements)
- graphical presentations (Plots)

Example File for Absolute Gravity Data – Observations –
"Set" Output File of g-Software

```
Source Data Filename: HON_AC_301_220603a
g Acquisition Version:  1.0309
g Processing Version:  2.0807
Set   Time        DOY   Year  Gravity          Sigma       Error Uncert  Tide       Load       Baro       Polar
Datum        Refxo        Temp       Pres       Accept Reject
   1  10:09:17    173   2003  981900628.855     22.179      1.817 1.817 -19.722      0.000     -0.929      0.446
15.511        0.866      22.434     996.652      149      1
   2  11:09:18    173   2003  981900639.550     20.995      1.714 1.714 -23.235      0.000     -1.015      0.446
15.511        0.877      22.237     996.366      150      0
   3  12:09:18    173   2003  981900634.067     21.884      1.787 1.787 -26.210      0.000     -1.102      0.446
15.511        0.861      22.181     996.076      150      0
   4  13:09:14    173   2003  981900636.078     20.771      1.702 1.702 -28.010      0.000     -1.158      0.446
15.511        0.879      22.191     995.890      149      1
   5  14:09:19    173   2003  981900631.653     22.360      1.832 1.832 -28.620      0.000     -1.153      0.446
15.511        0.872      22.267     995.905      149      1
   6  15:09:18    173   2003  981900639.902     20.334      1.660 1.660 -28.597      0.000     -1.287      0.446
15.511        0.858      22.366     995.457      150      0
   7  16:09:16    173   2003  981900637.906     19.430      1.597 1.597 -28.889      0.000     -1.330      0.446
15.511        0.868      22.317     995.316      148      2
   8  17:09:19    173   2003  981900634.061     18.351      1.503 1.503 -30.538      0.000     -1.401      0.446
15.511        0.863      22.293     995.080      149      1
   9  18:09:18    173   2003  981900633.804     17.651      1.441 1.441 -34.355      0.000     -1.414      0.446
15.511        0.862      22.307     995.035      150      0
  10  19:09:18    173   2003  981900632.501     15.694      1.281 1.281 -40.645      0.000     -1.372      0.446
15.511        0.865      22.309     995.177      150      0
  11  20:09:24    173   2003  981900636.117     16.760      1.378 1.378 -49.049      0.000     -1.269      0.446
15.511        0.864      22.387     995.520      148      2
  12  21:09:18    173   2003  981900635.819     18.957      1.548 1.548 -58.449      0.000     -1.222      0.446
15.511        0.864      22.354     995.676      150      0
  13  22:09:18    173   2003  981900634.311     17.149      1.400 1.400 -67.286      0.000     -1.117      0.446
15.511        0.885      22.364     996.026      150      0
  14  23:09:18    173   2003  981900635.878     17.384      1.419 1.419 -73.712      0.000     -1.161      0.446
15.511        0.864      22.350     995.878      150      0
  15  00:09:18    174   2003  981900635.270     15.541      1.269 1.269 -76.077      0.000     -1.067      0.446
15.511        0.863      22.345     996.191      150      0
  16  01:09:18    174   2003  981900634.388     15.593      1.273 1.273 -73.324      0.000     -1.228      0.446
15.511        0.873      22.351     995.654      150      0
```

Graphical documentation of the absolute Gravity Measurements



Outside view of the station during measurement

Instrument set-up at the station during measurement

Absolute Gravimeter Meta Data Base (Draft)

ECGN-Project

Example for a Meta-Database for Absolute Gravity Observations

Station	Date	Instrum.	Number of sets	Drops per set	Total drops	Comment	Reference to database
	2003						
Bad Homburg	23. Jan.	101	2	150	300		BadHom.2003a
Bologna	29. Jan.	101	25	150	3750		Bologna.2003a
Medicina	1. Feb.	101	25	150	3750		Medicina.2003a
Bad Homburg	9. Feb.	101	48	150	7200		BadHom.2003b
Bad Homburg	10. Feb.	101	12	150	1800	Comp. FG5-220	BadHom.2003c
Walferdange	11. Mrz.	101	13	150	1950	Comp. FG5-202 and FG5-216	Walferdange.2003a
Wettzell	3. Apr.	101	25	150	3750		Wettzell.2003a
Bad Homburg	24. Apr.	101	25	150	3750		BadHom.2003c
Helgoland	27. Apr.	101	49	150	7350		Helgoland.2003a
Moxa	15. Mai.	101	48	100	4800		Moxa.2003a
Sassnitz	17. Mai.	101	46	150	6900		Sassnitz.2003a
Bad Homburg	3. Jun.	101	26	150	3900		BadHom.2003d
Bad Homburg	9. Jun.	101	28	150	4200		BadHom.2003e
Stavanger (N)	17. Jun.	101	25	150	3750		Stavanger.2003
Hönefoss (N)	22. Jun.	101	25	150	3750		Hönefoss.2003
Trysil (N)	24. Jun.	101	25	150	3750		Trysil.2003
Vagstranda (N)	26. Jun.	101	25	150	3750		Vagstranda.2003
Trondheim (N)	28. Jun.	101	25	150	3750		Trondheim.2003
Tromsoe (N)	3. Jul.	101	25	150	3750		Tromsoe.2003
Kiruna (S)	6. Jul.	101	25	150	3750		Kiruna.2003
Furoeregrund (S)	9. Jul.	101	25	150	3750		Furoeregrund.2003
Martsbo (S)	12. Jul.	101	25	150	3750		Martsbo.2003
Onsala (S)	15. Jul.	101	32	150	4800		Onsala.2003
Bad Homburg	19. Jul.	101	25	150	3750		BadHom.2003f
Wettzell	14. Aug.	101	25	150	3750		Wettzell.2003b
Medicina	17. Aug.	101	35	150	5250		Medicina.2003b
Bologna	19. Aug.	101	25	150	3750		Bologna.2003b
Bad Homburg	27. Sep.	101	49	150	7350		BadHom.2003g
Walferdange,B1	4. Nov.	101	15	100	1500		Walferdange.2003
Walferdange C1	5. Nov.	101	23	100	2300		Walferdange_C1

	2004						
Wettzell	9. Jan.	301	25	150	3750		Wettzell.2004a
Medicina	11. Jan.	301	25	150	3750		Medicina.2004a
Bologna	13. Jan.	301	25	150	3750		Bologna.2004a
Bad Homburg	26. Jan.	101	101	150	15150		BadHom.2004b
Moxa	17. Feb.	301	72	100	7200		Moxa.2004a
Bad Homburg	3. Mrz.	301	25	150	3750		BadHom.2004b
Strasburg A	30. Mrz.	301	23	150	3450		Strasburg.2004
Bad Homburg	5. Mai.	301	17	150	2550		BadHom.2004c
Moxa	20. Jun.	101	40	100	4000		Moxa.2004b
Bad Homburg	22. Jun.	301	25	150	3750		BadHom.2004d
Metsähovi	11. Jul.	301	81	150	12150		Metsähovi.2004
Bad Homburg	29. Jul.	301	36	150	5400		BadHom.2004e
Medicina	25. Aug.	301	34	150	5100		Medicina.2004b
Bologna	28. Aug.	301	30	150	4500		Bologna.2004b
Pecny	2. Nov.	101	33	150	4950		Pecny.2004
Bad Homburg	3. Nov.	301	21	150	3150		BadHom.2004f
Wettzell	5. Nov.	101	43	150	6450		Wettzell.2004b
	2005						
Medicina	8. Jan.	101	34	150	5100		Medicina.2005a
Bologna	11. Jan.	101	30	150	4500		Bologna.2005a
Bad Homburg	24. Jan.	101	21	100	2100		BadHom.2005a
Moxa	8. Mrz.	101	25	100	2500		Moxa.2005a
Wettzell	10. Mrz.	101	24	150	3600		Wettzell.2005a
Bad Homburg	5. Apr.	101	15	150	2250	Comp. FG5-220	BadHom.2005b

In addition it was identified that some additional information will be important for the interpretation of the gravity determination like

- reduction from an eccentric occupation to the station center
- ground water data etc.

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.

IV. Real Time

ECGN/EUREF-IP stations (10):

A Coruna	Spain	
Almeria	Spain	
Caceres	Spain	
Santander	Spain	
Ceuta	Spain	
Ondrejov	Szech Republic	
Palma de Mallorca	Spain	
Maartsbo	Sweden	
Saßnitz	Germany	
Valencia	Spain	

V. EVRS Datum Definition

EVRS Conventions

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**

datum

geocentric, including oceans and atmosphere

***W_0* independend 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)

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

frame

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.

EVRS Realization (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

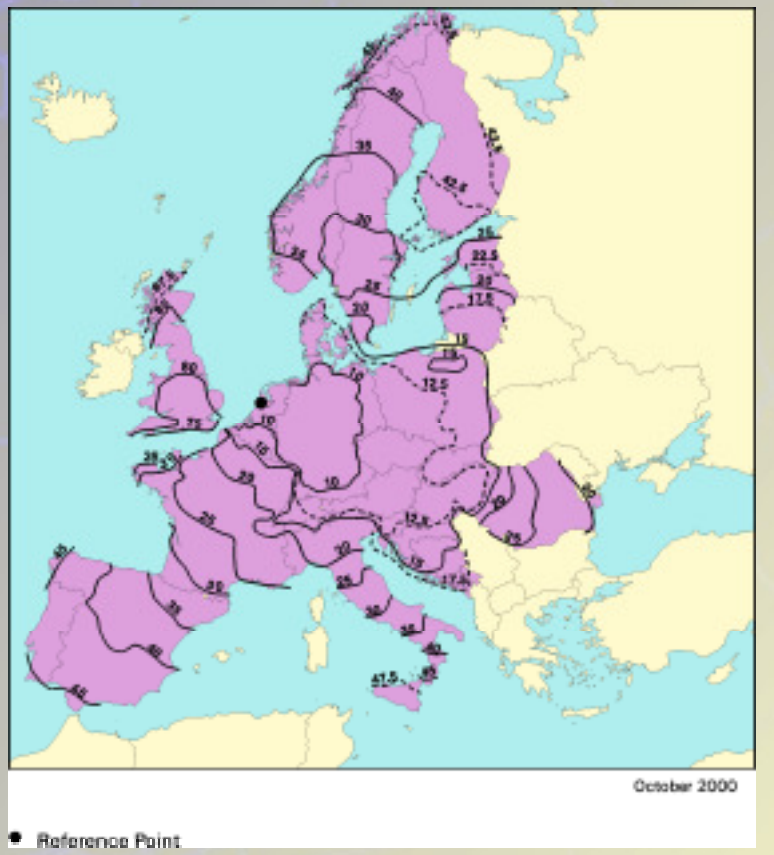
$$W_{NAP}^{REAL} = U_{0GRS80}$$

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.

Frame

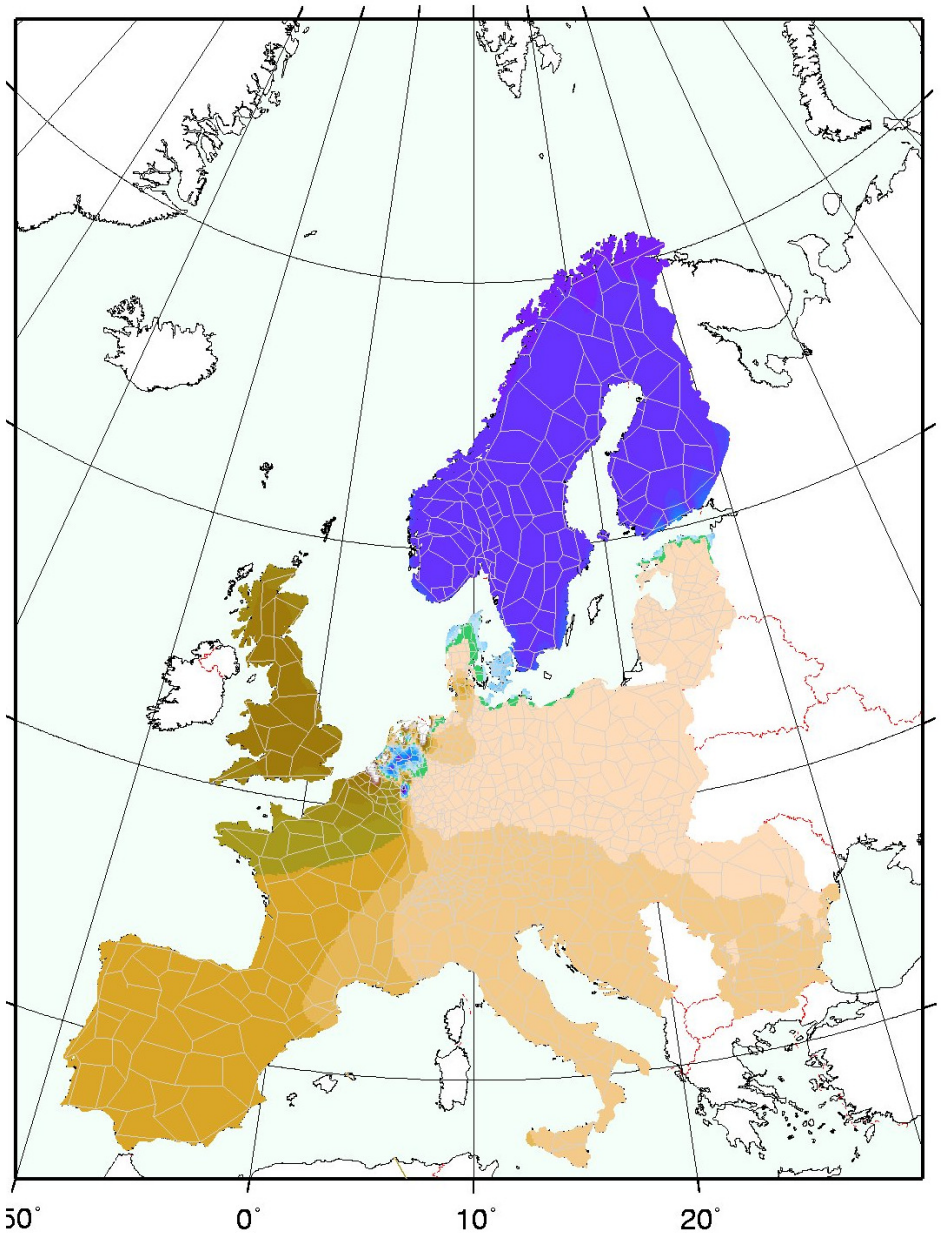
The adjustment of geopotential numbers was performed as an unconstrained adjustment linked to the reference point of UELN 73 (in NAP). In January 1999, the adjustment version UELN 95/13 was handed over to the participating countries as the UELN 95/98 solution.

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

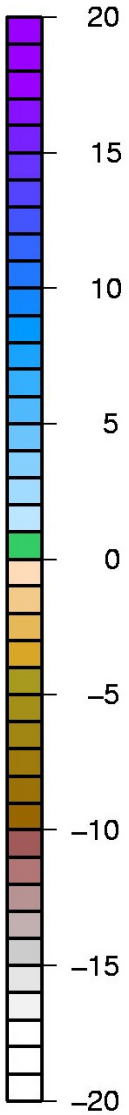


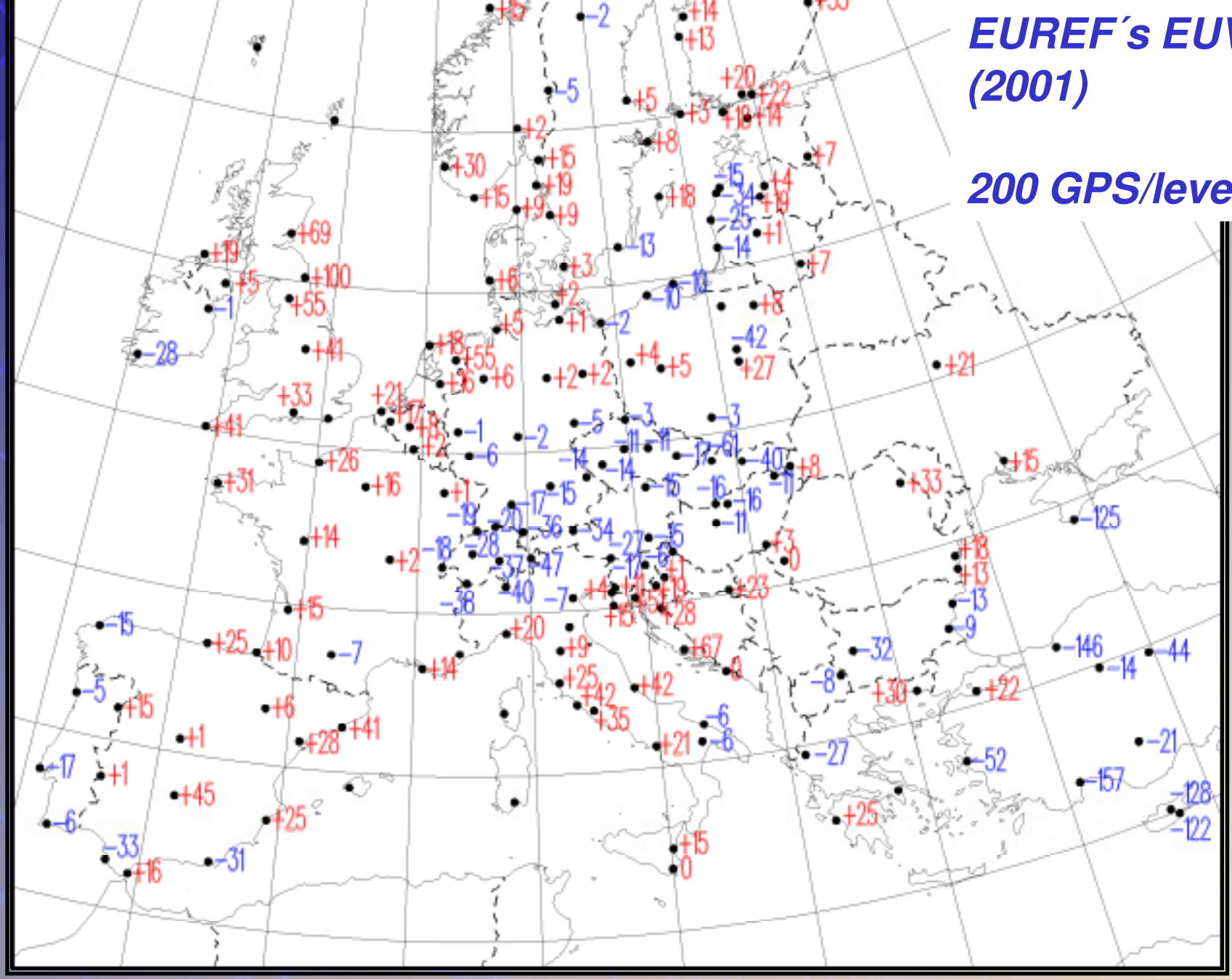
UELN 95/98 – Isolines of Precision [kgal · mm]

Differences to the heights of the last UELN adjustment version with 23 datum points all over Europe



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





EUREF´s EUVN project (2001)

200 GPS/levelling points

Differences between gravimetric height components and GPS heights

$(\zeta_{EGG97} + H_{EUVN}) - h_{ITRS}$

Recommendations for EVRS:

1. The EVRS datum definition is fixed
2. EVRS needs a new realization for the Datum
3. A new realization the frame is useful and possible

EVRS frame realization (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)

For countries which are not member of UELN the fitted European geoid can used

EVRS 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*

and GPS heights h_p

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

$$H_n = h_P - \zeta$$

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

ii. Height Datum

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

Definition:

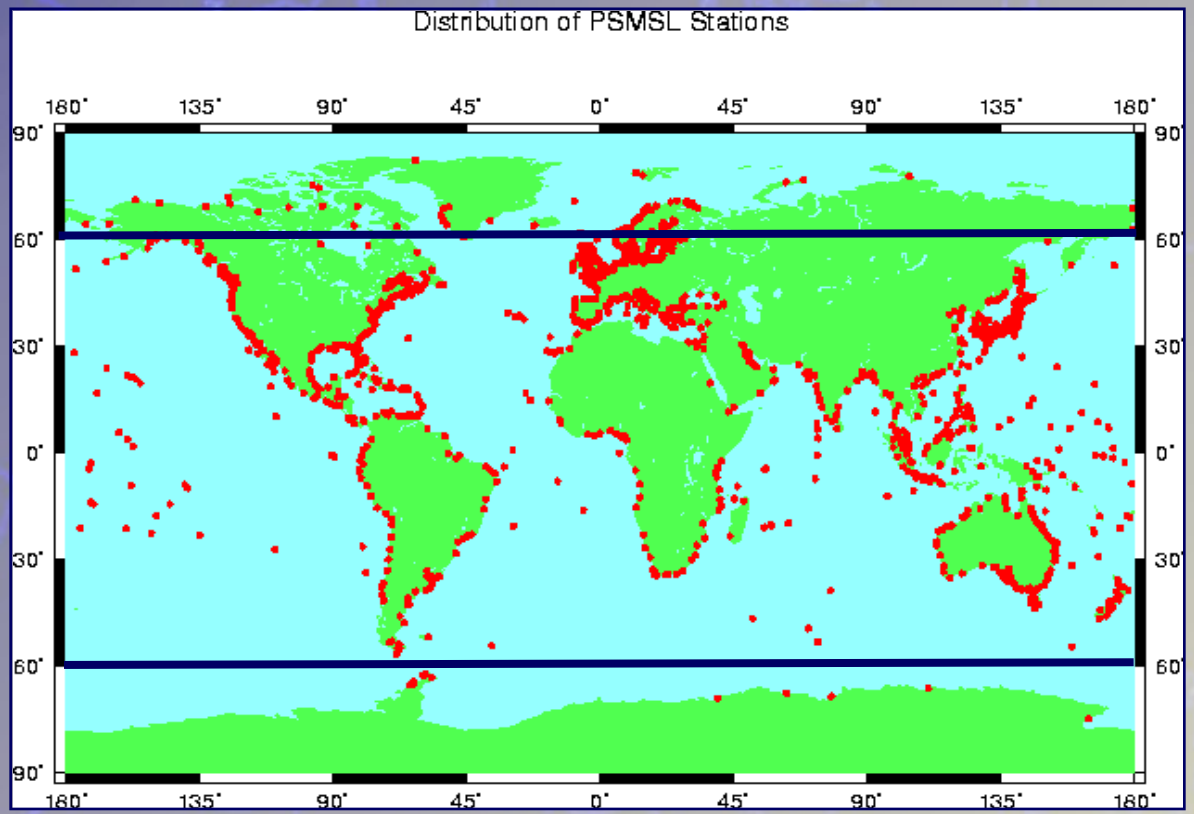
- **The level of the equipotential surface of a World Height System (WHS) is the mean sea surface – MSL**
- **The ellipsoid shall have the same scale – mean Earth ellipsoid (geocentric) - ME**
- ***Convention:*** $U_o^{ME} = W_o^{MSL}$

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, ...)

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**

TIME VARIATIONS OF HEIGHTS

- **SEASONAL VARIATIONS**
  - **compare SG variations with GRACE data**
  - **mass variations (from GRACE) give surface loading changes and hence seasonal variations in GPS/SLR/VLBI**
- **SECULAR VARIATIONS**
  - **GPS vertical rates have accuracy of 2-3mm/year (reference frame)**
  - **AG obs. give independent vertical rates**
  - **also compare EPN at coastline with geological rates and tide gauge rates.**

(4) Concept of the Realization of a World Height System (WHS)

Unification:

Rummel/Teunissen 1988, Brovar 1988, Rapp 1992/1994, Kakkuri 1994, IAG SSG´s, Kearsely 1998, Bursa 2001, ...

WHS:

Bruns 1878, Mineo 1933, Brovar 1958,

Bursa 1991/1999/2001, Yurkina 1996, EUREF 2001,

Kouba 2001, Hipkin 2001, ...

Elements of a physical height system

i. **Reference surface**
ii. **Height datum**
iii. **Vertical component (height)**

- Definitions of the elements
- Conventions for the realization including handling of the time variation of Earth, measurements and parameters

Working concept:

The Earth surface P (solid and fluid) is determined by its geometry X_P and the potential of the Earth gravity field W_P on it at any time.

i. Reference Surface

- **physical heights:**

  equipotential surface of the Earth gravity field W_0 coinciding with sea level

  (in sea level is geoid = quasigeoid)

- **geometrical heights:**

  ellipsoid (equipotential surface of the normal Earth gravity field U_0)

ii. Height Datum

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

Definition:

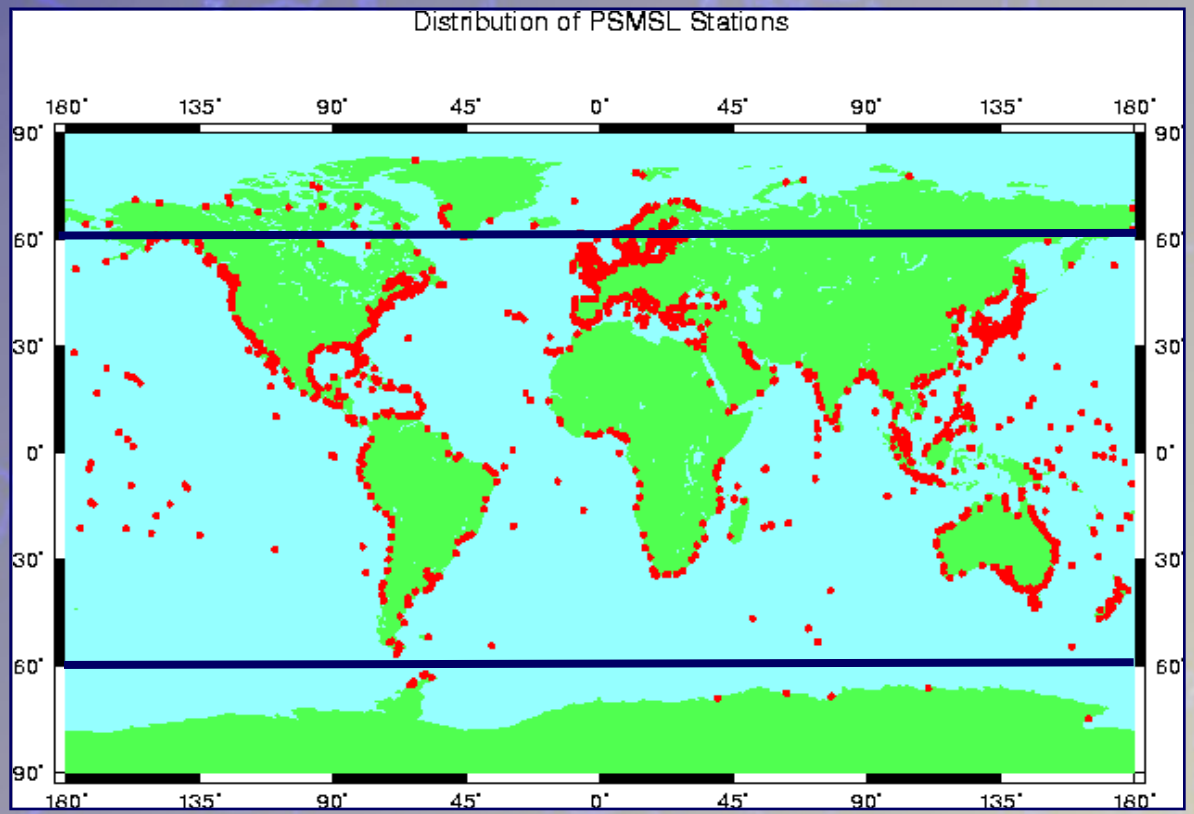
- **The level of the equipotential surface of a World Height System (WHS) is the mean sea surface – MSL**
- **The ellipsoid shall have the same scale – mean Earth ellipsoid (geocentric) - ME**
- ***Convention:*** $U_o^{ME} = W_o^{MSL}$

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, ...)

iii. Vertical component

- **geopotential of the Earth surface W_P in relation to the reference surface (geopotential numbers):**

  $W_0 - W_P = c_P$,

- **in equivalence a physical height on the basis of c_P can be used**

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.

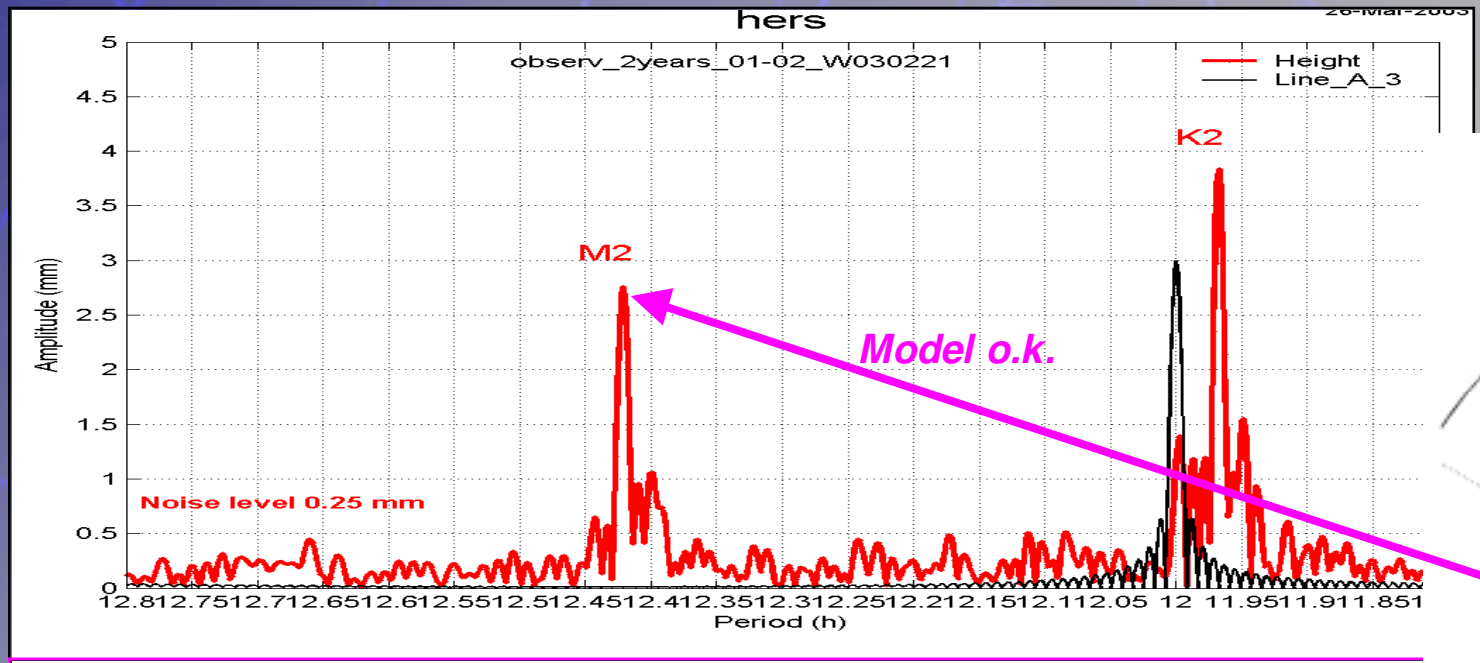
Relations between ITRS and EVRS/WHS - 2 -

ITRS	WHS/EVRS
coordinates	
quasi – Cartesian system X	potential of the Earth gravity field $W_p = W(X)$ $= U_p + T_p$ (GGM) $= W_o - C_p$ (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

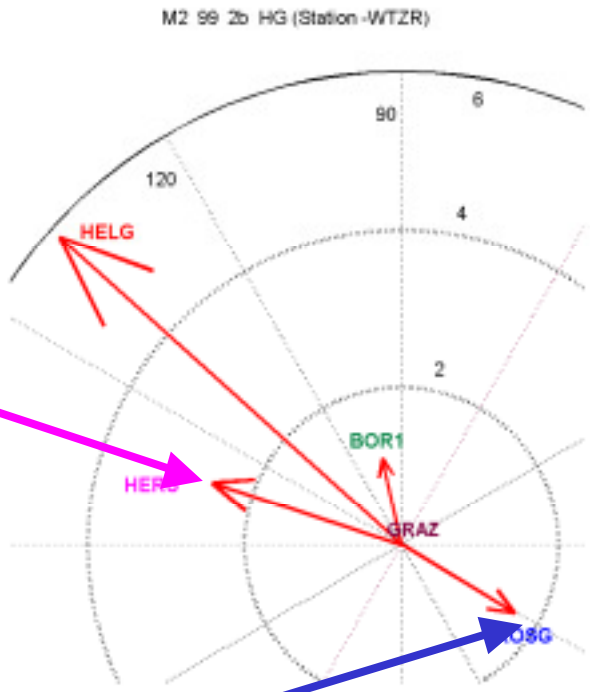
	gravity	geoid	levelling height	altimetry	mean sea level	position
	g/Δg	W/N	ΔH	h	msl	X/h
Mean tidal system **Mean/zero crust** (Stokes is not valid if masses outsite the Earth surface)	Δg_m	N_m	ΔH_m	Relation to N_m for oceanographic studies	h_{msl}	
Zero tidal system **Zero/mean crust** (Recommended by IAG Res. No. 16, 1983)	$\Delta g_z \xrightarrow{\text{Stokes}} N_z$ (EGG97)		(EVRF 2000) ΔH_z			
Non-tidal system **Non-tidal crust** (far away from the real earth shape – there is no reason for the non tidal concept)	$\Delta g_n \xrightarrow{\text{Stokes}} N_n$ (EGM96)					X_n ITRFxx, ETRS89

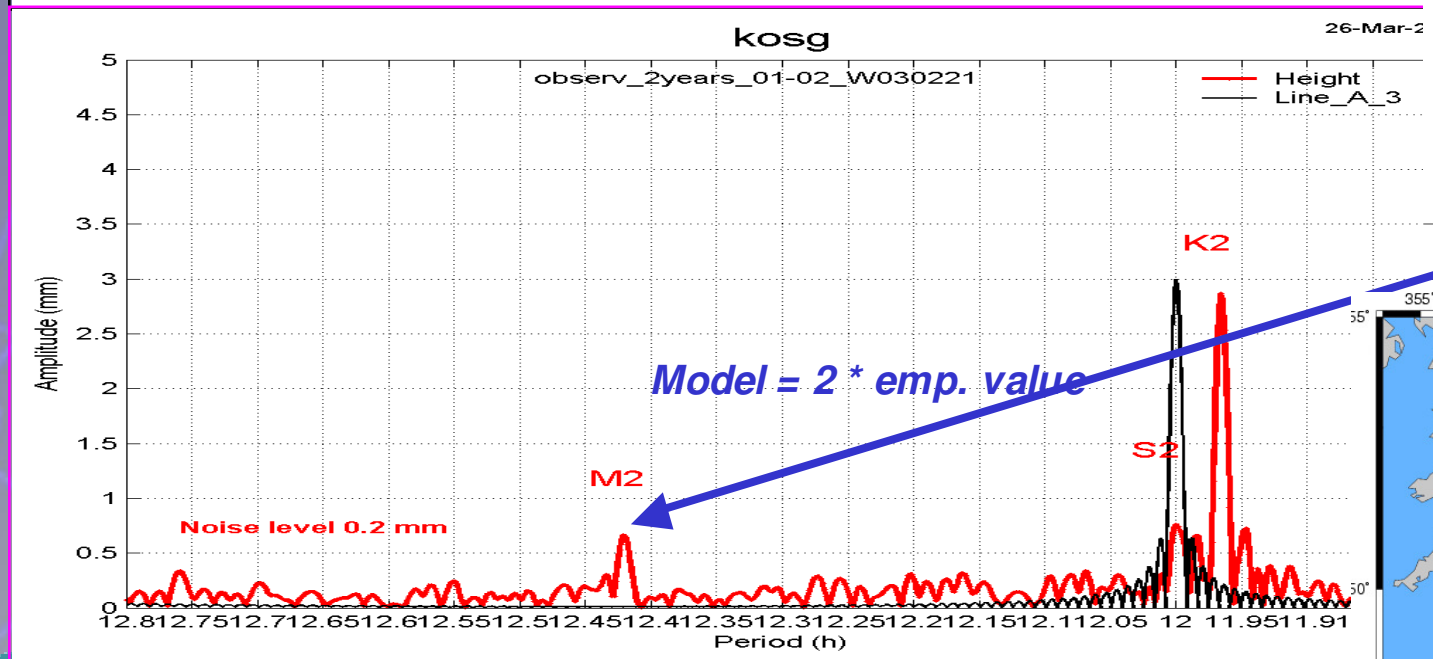
Bundesamt für Kartographie und Geodäsie

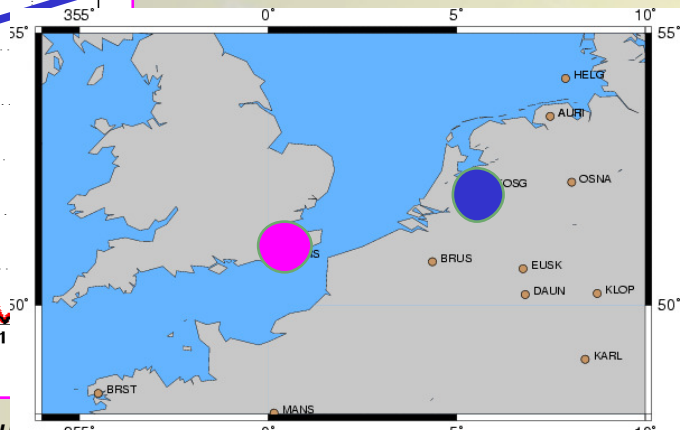
DGPS in Ocean loading: Differences over short distances



Vectordiff of vertical loading for (Site) - WTZR

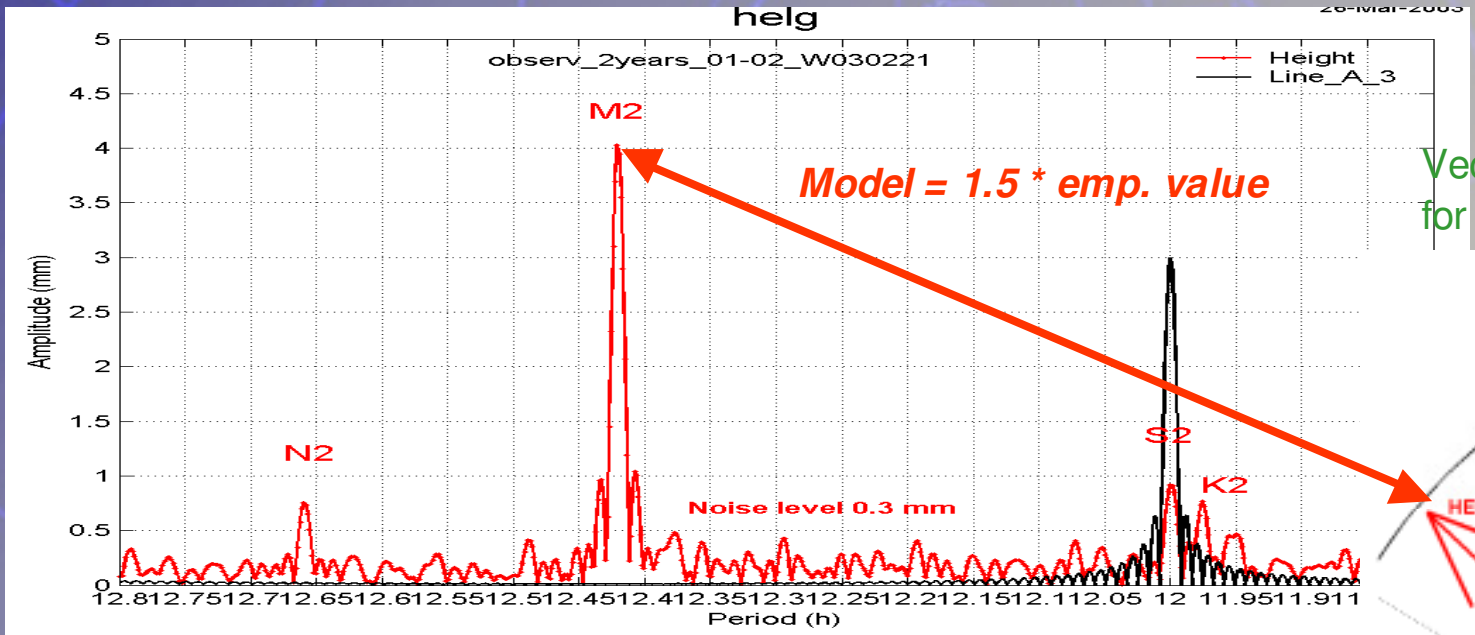






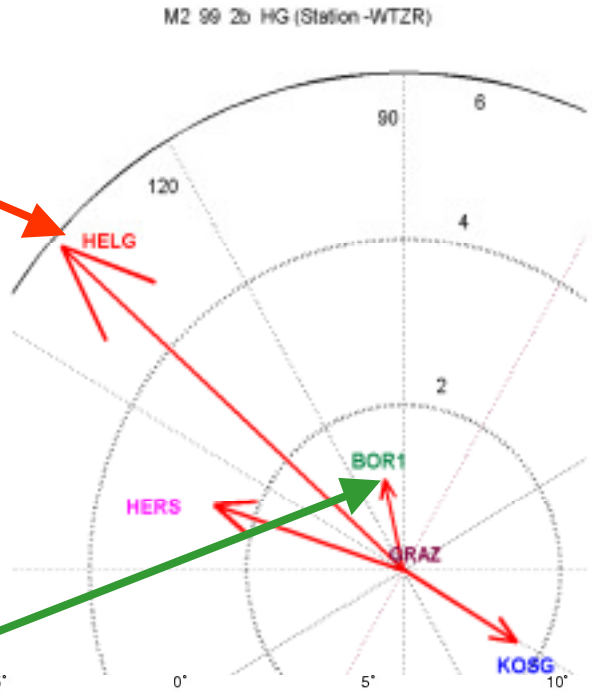
Bundesamt für Kartographie und Geodäsie

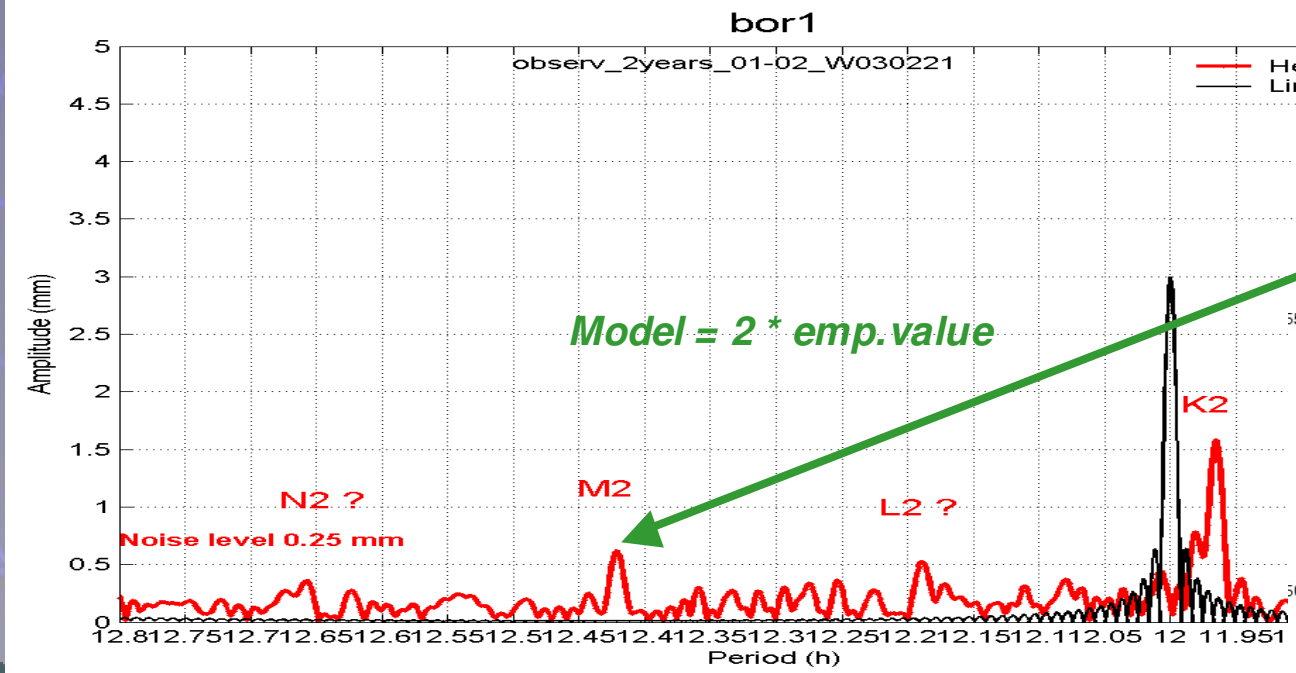
DGPS in Ocean loading: Island vs. Continental site



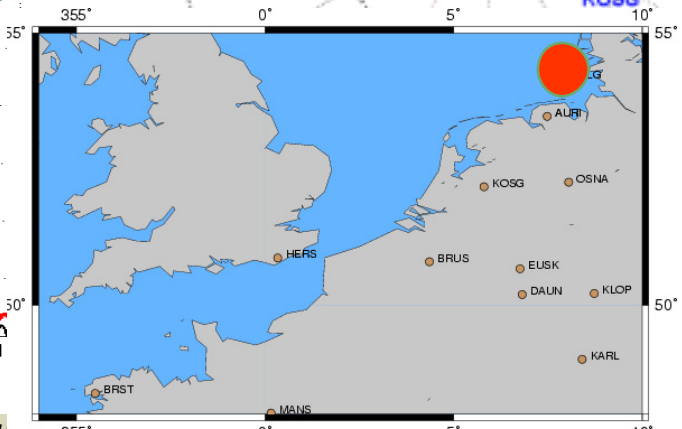
Model = 1.5 * emp. value

Vectordiff of vertical loading for (Site) - WTZR



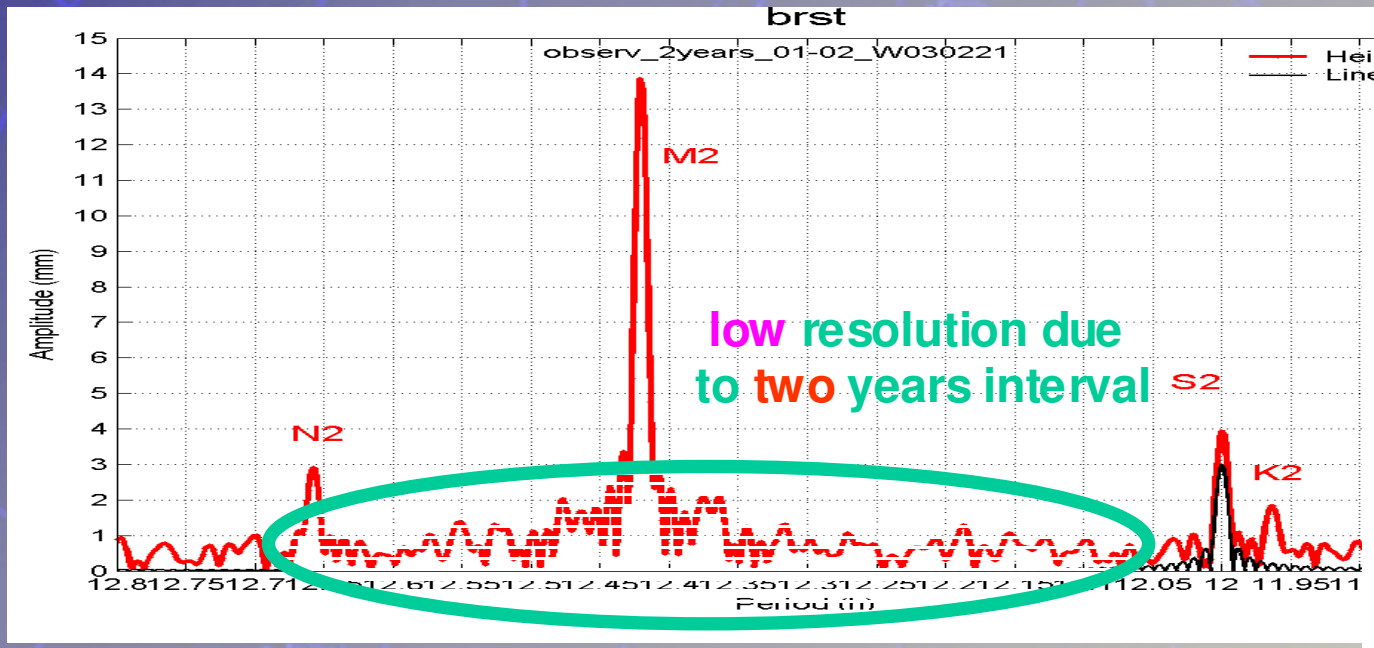


Model = 2 * emp.value

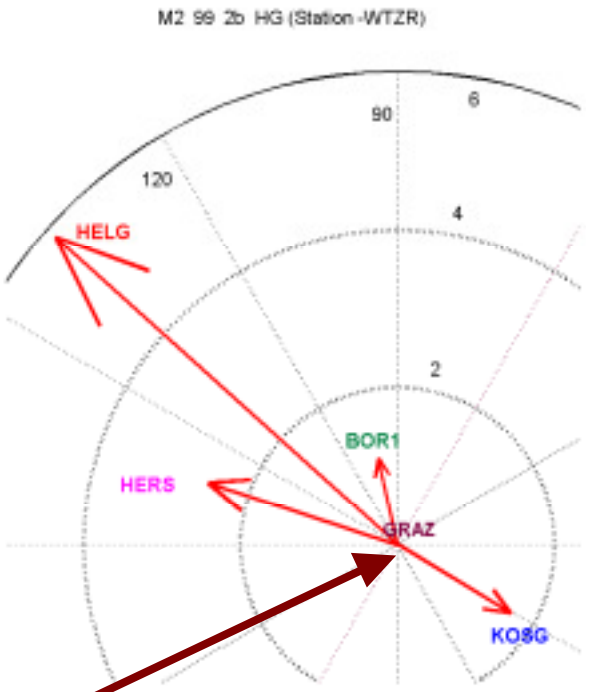


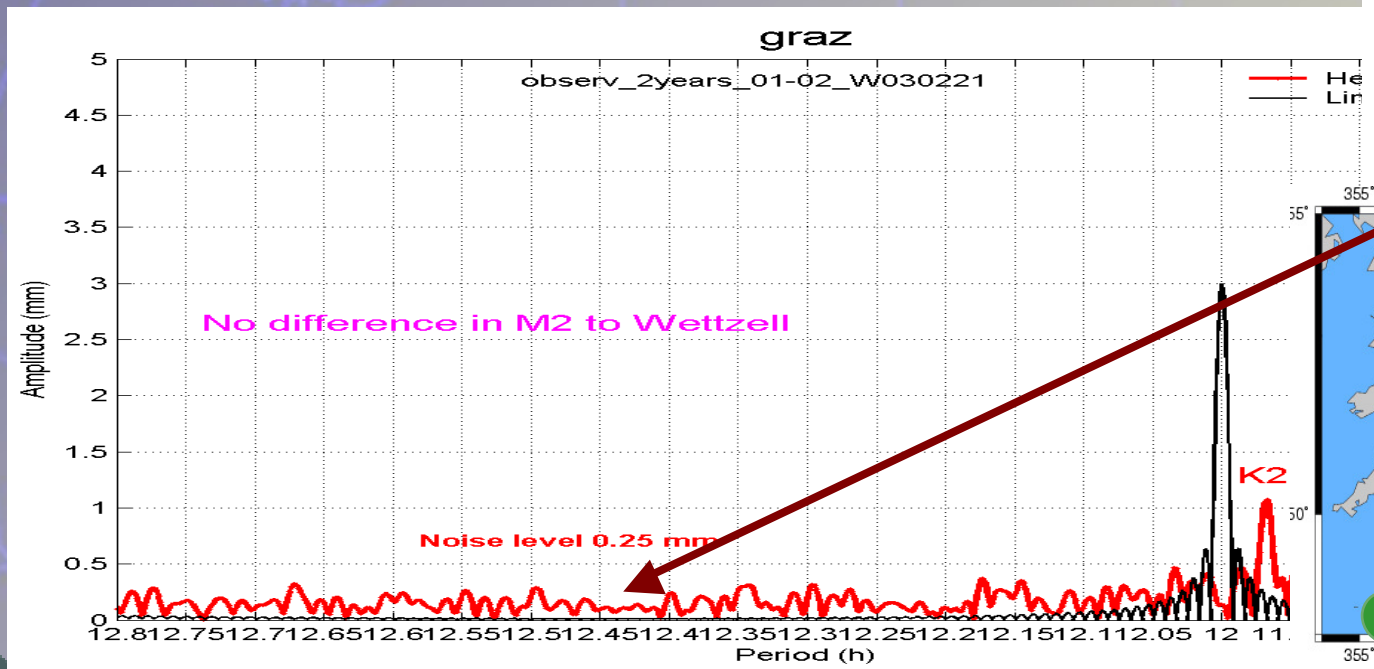
Bundesamt für Kartographie und Geodäsie

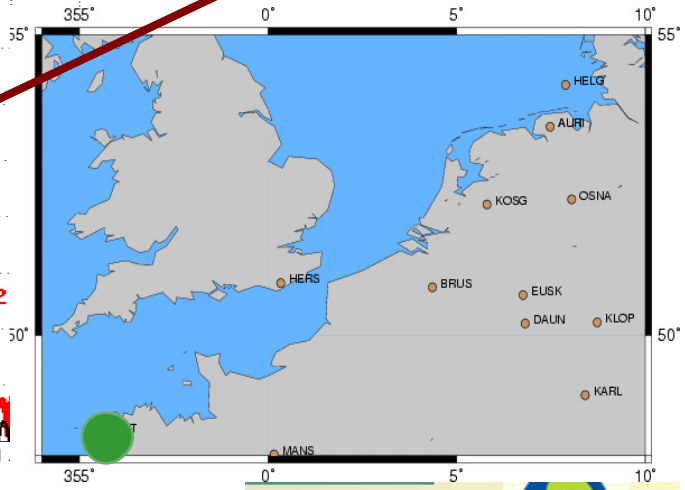
DGPS in Ocean loading: Spectral resolution (1)



Vectordiff of vertical loading for (Site) - WTZR

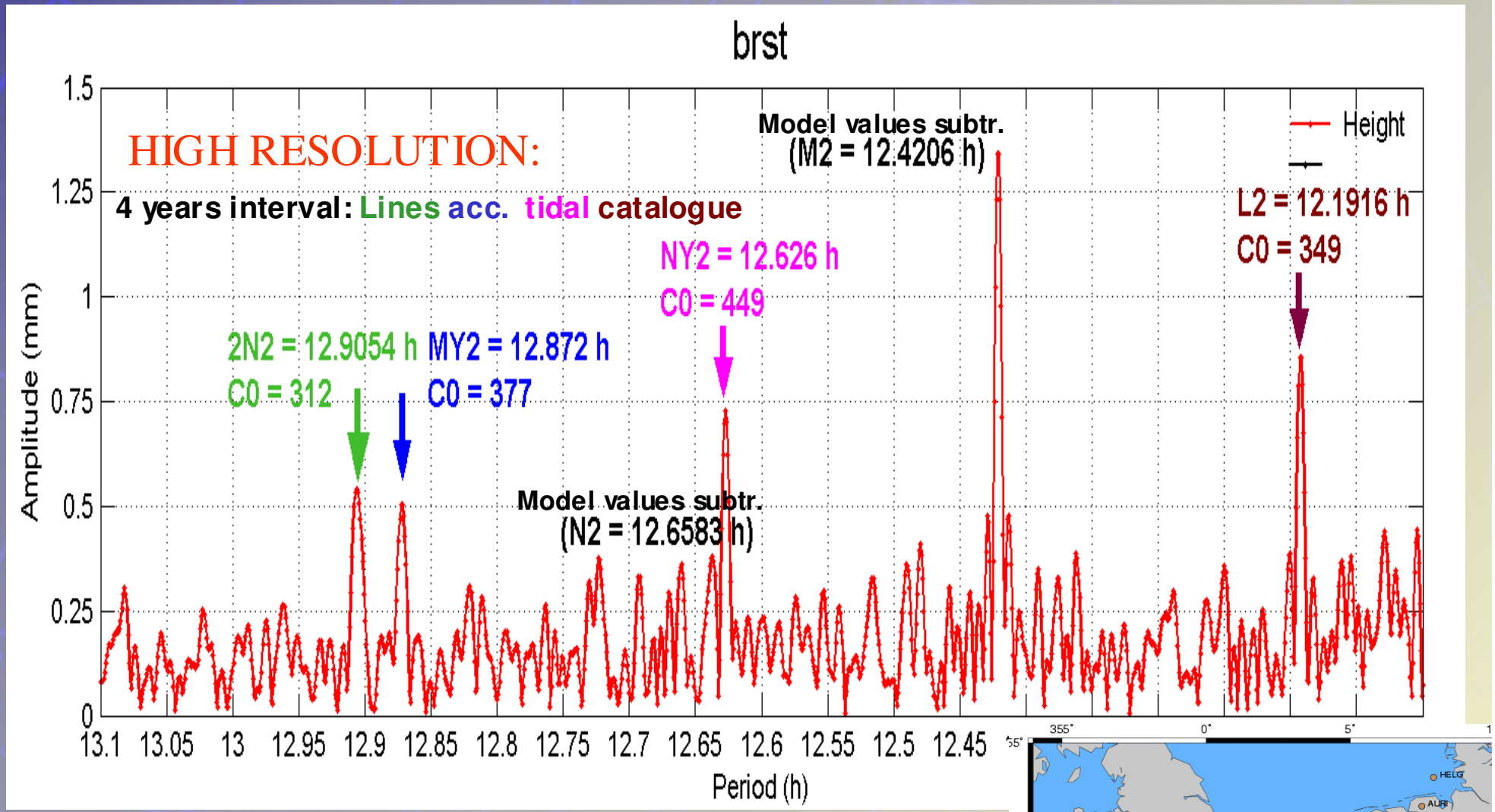


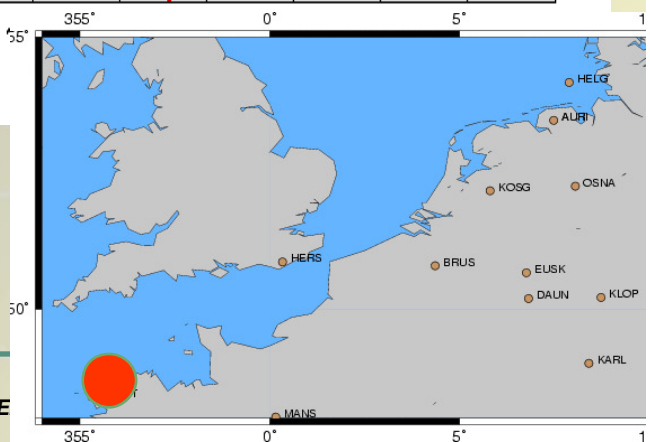




Bundesamt für Kartographie und Geodäsie

DGPS in Ocean loading: Spectral resolution (2): residuals





Objectives

ECGN

Integrated European Reference System for Spatial Reference and Gravity

- Maintenance of long time stability of the terrestrial reference system with an accuracy 10^{-9} for Europe especially in the height component
- In-situ combination of geometric positioning (GPS) with physical heights and other Earth gravity parameters in 1 cm-accuracy level
- Modelling of influences of time depended parameters of the solid Earth of the Earth gravity field, the atmosphere, the oceans, the hydrosphere for different applications of positioning

- Contribution to the European gravity field modelling as contribution to a global gravity model
- Modelling of gravity field components to validate the satellite gravity missions CHAMP, GRACE und GOCE
- Platform for further geo-components (GMES, GEOSS, GGOS)

ECGN Standards and Guidelines

- for each main observation technique (GPS, gravity measurements, levelling, tide gauge) guidelines and forms for acquisition of data were prepared
- they include details about the execution of measurements, the expected accuracy as well as information about collecting of data
- generally already existing data bases will be used for ECGN project

Guidelines (iii)

- **Levelling**
  - all ECGN stations should be connected to the United European Levelling Network - UELN (see http://evrs.leipzig.ifag.de)
  - the rules for connection the ECGN station to UELN are described in the guideline and the corresponding measurements data should be registered in the ECGN Levelling Form
  - ECGN Standards Levelling Connection of the ECGN Station and Levelling Form (see ECGN Website – PDF/DOC File)
- **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
  - ECGN Standards for Tide Gauge measurements (see ECGN Website – PDF File)

Guidelines (iv)

- **Local Ties**
  - the observation of different techniques should be in a close range according to the conditions of the ECGN station
  - each type of observation has its own marker and one marker has to be declared as main marker
  - to this marker the local ties have to be known
  - ECGN Standard for Local Ties Determination (see ECGN Website – PDF File)

To contribute physical heights to global cm geodesy it needs:

- a unique global datum
- consistency of parameters, models and processing procedures with ITRS and gravity field determination
- a closed theory for the combination with other parameters (space techniques, gravity)
- consideration of time depended influences
- realization concepts