Federal Agency for
Cartography and Geodesy

Activities of BKG LAC and the connections of EPN to the German official geodetic spatial reference

Peter Franke

My Topics:

- Information about the main Control-Networks at BKG
- Definition of the (new) spatial reference frame in Germany
- First tests with Multi-GNSS, especially Galileo Observations and RINEX v3 in Bernese GNSS Software Vers. 5.2

BKG Control-Networks

- EPN LAC
  - Since 1997 (now 20 years)
  - Approx. 120 stations
  - BSW 5.2 since 2013

- DREFonline
  - Joint effort of AdV*) and BKG
  - Since 2007 (now 10 years)
  - Approx. 85 stations
  - BSW 5.2 since 2013
  - First tests with Galileo observations

*) Working Committee of the Surveying Authorities of the Länder of the Federal Republic of Germany (AdV)

BKG Control-Networks

- EPN LAC

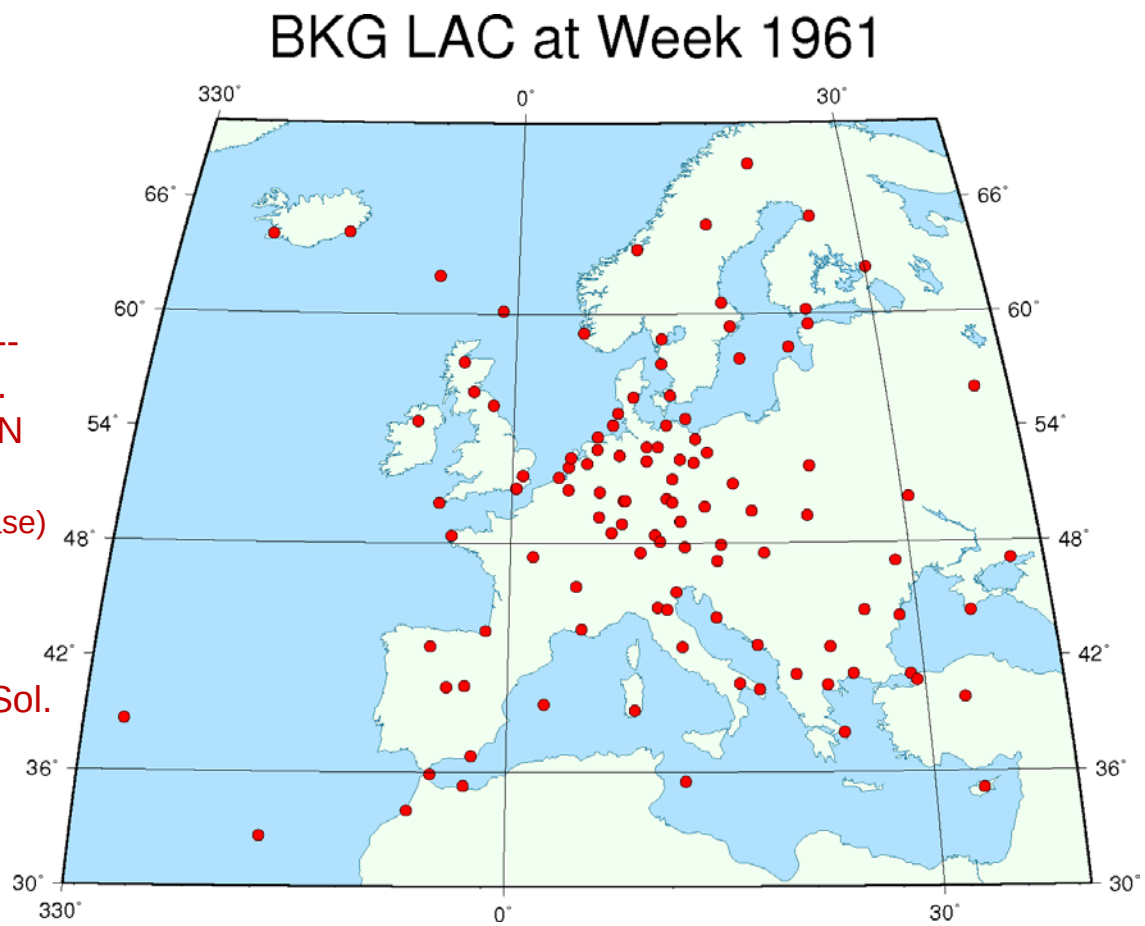
117 Stations

Status Oct. 2017

Standard analysis w.r.t.
to the guidelines of EPN

Bernese 5.2 (latest release)

- GPS + GLO
- CODE Final Orbits
- Minimum Constraint Sol.
- Daily + weekly Sol.
- Daily Rapid Sol.



BKG Control-Networks

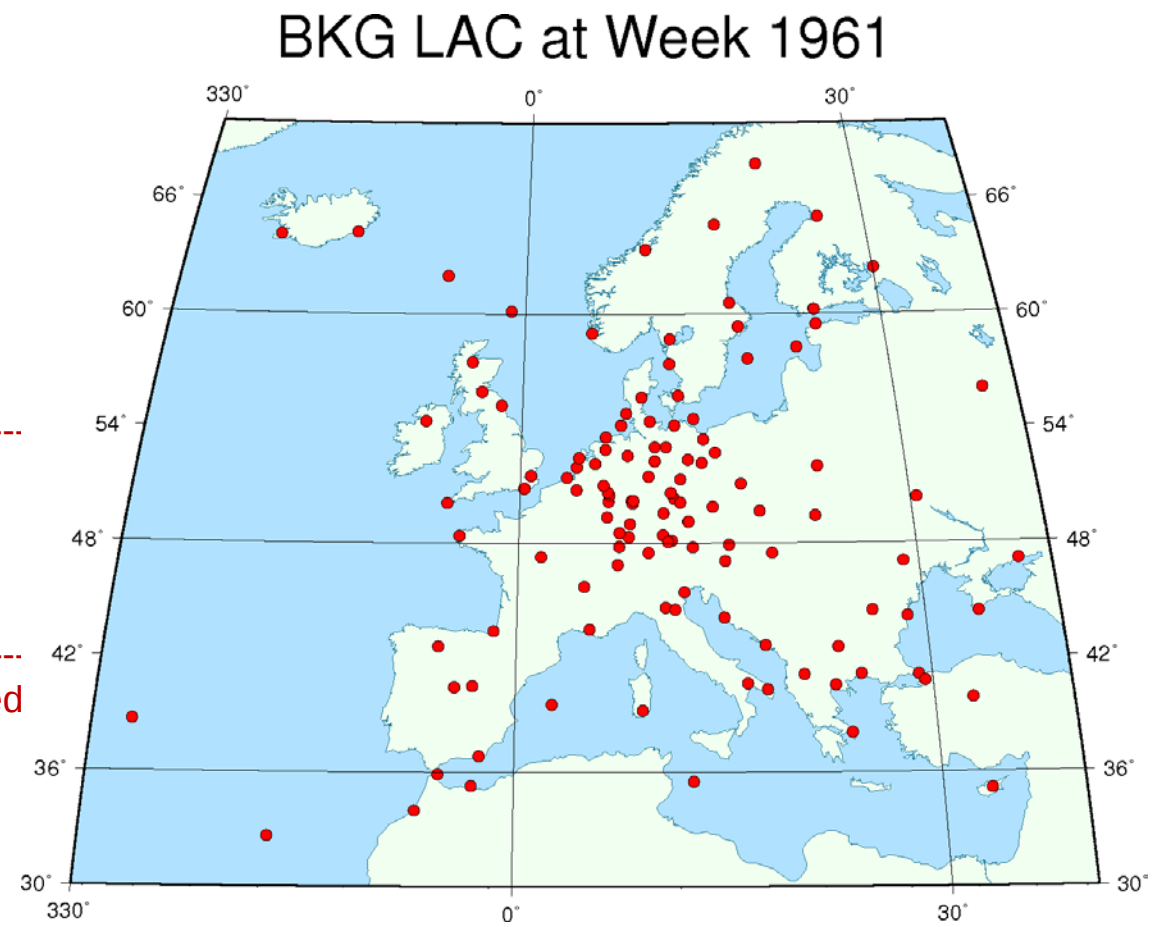
- EPN LAC

Extension to 135 Stations

117 actual EPN +
18 additional sites

Distribution done by **ADDNEQ2** due to entries in the **STA-file** (Type 3)

Results of the extended network are available at BKG data centre igs.bkg.bund.de in project **GREF**



Post-Processing

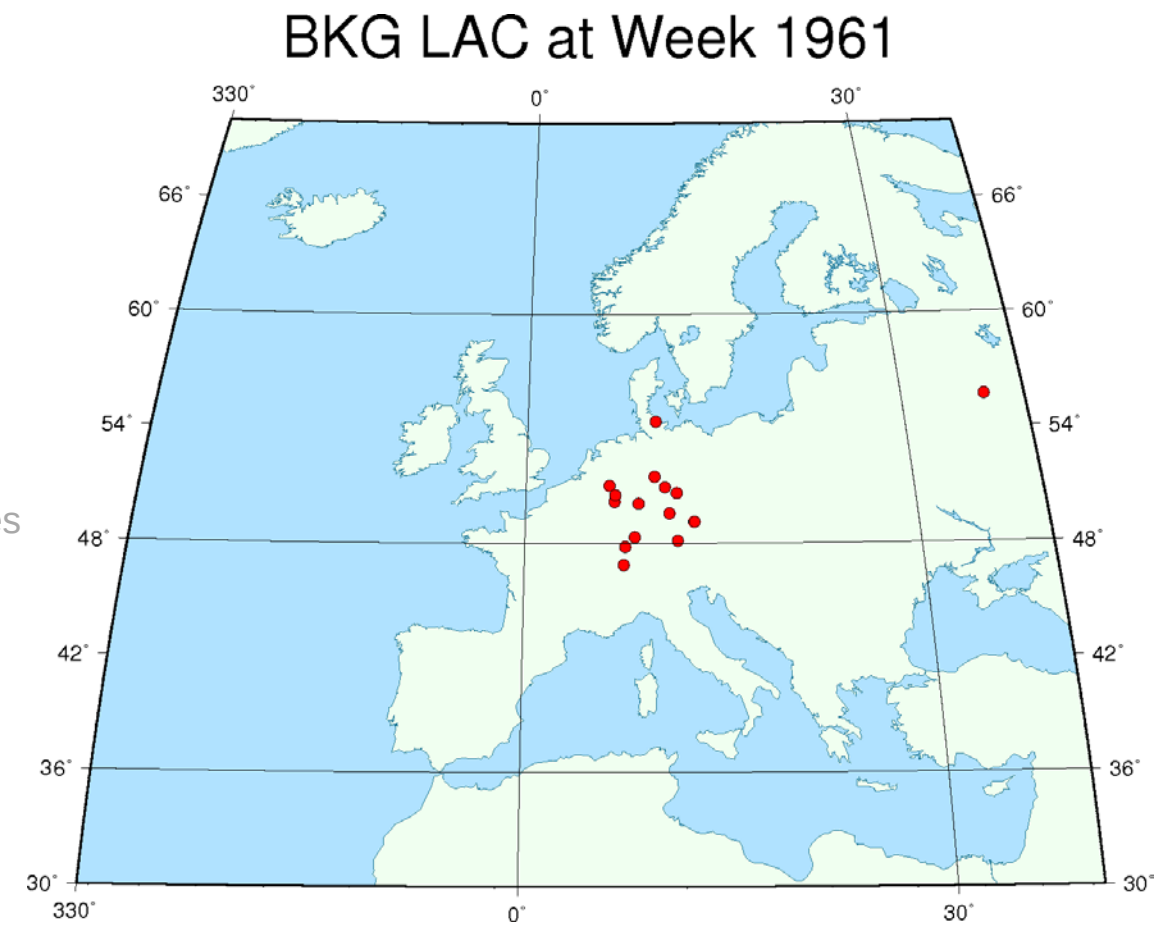
- EPN LAC

Extension to 135 Stations

Including:

- 13 addit. in GER
- ZIMM, ZIM2, ZWE2

- 2 proposed EPN sites



BKG Control-Networks

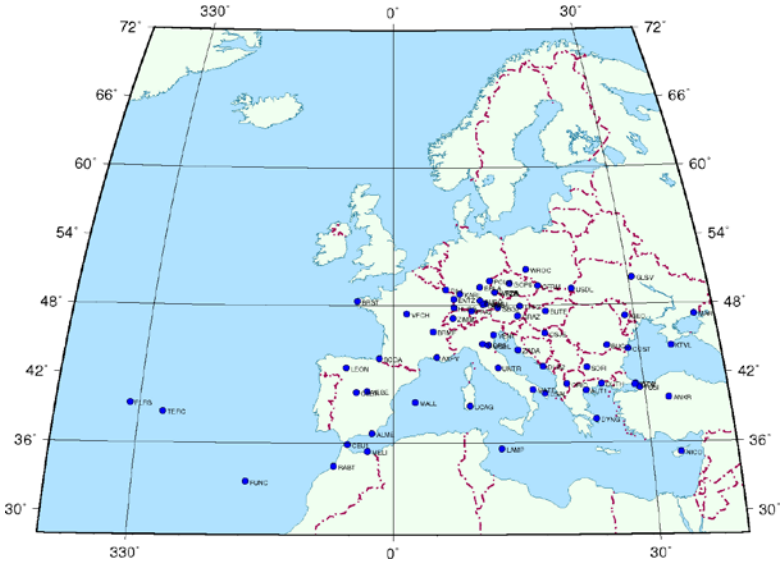
- EPN LAC

Extension to 135 Stations

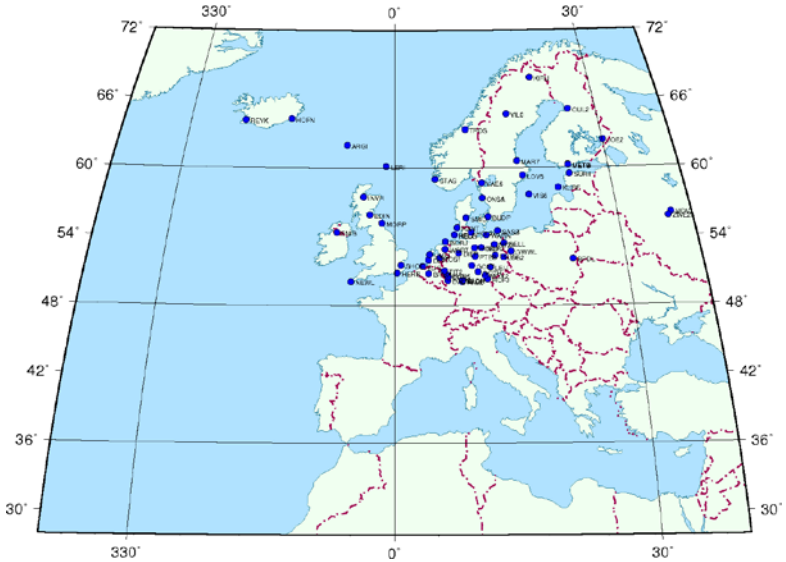
Clustering into 2 parts: Why ?

One cluster: Final GPSEST ~ 3 hours, 2 clusters: ~ 40 min.

BKG LAC CLU 1



BKG LAC CLU 2



BKG Control-Networks

- DREF online

Desciption
Control-Network for Monitoring the official coordinates of the Reference stations in the Federal States of Germany (**SA*POS*®**)

Network: *(about 85 Stations)*
34 SA*POS*®
31 BKG stations *(IGS, EPN,GREF)*
2 other in Germany *(GFZ / DLR)*
17 other IGS / EPN Stations

Bernese 5.2 GPS+GLO
Minimum-constraint solutions
Network-datum: IGS14 stations
Transformation to ETRS and DREF91

Comparison EPN ⇔ DREFonline

DREFonline ⇔ EPN

- DREF online

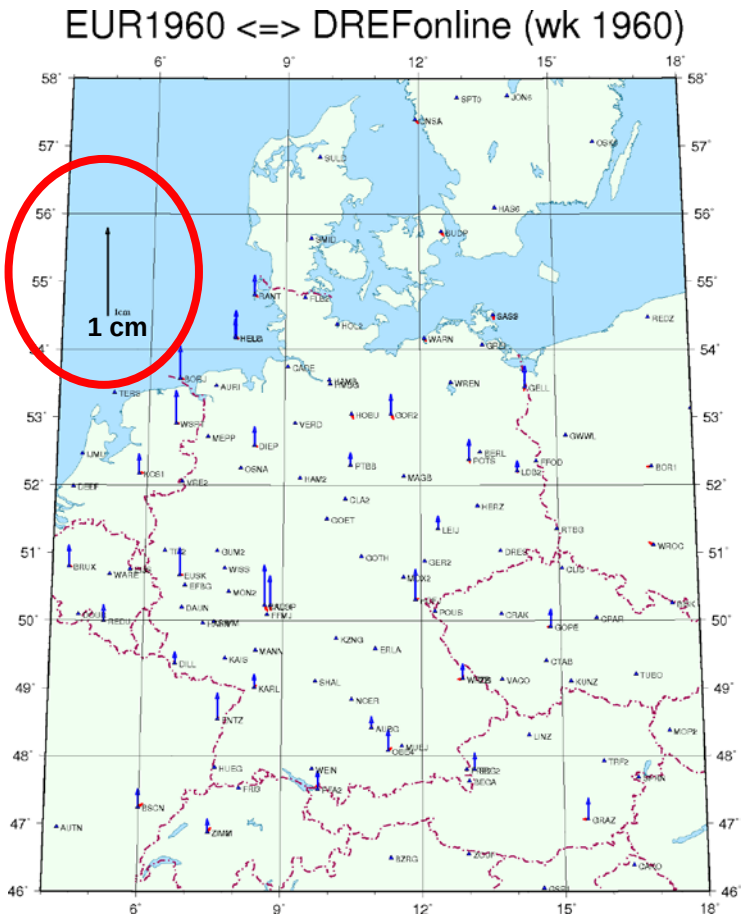
Comparison EPN ⇔ DREFonline

Absolute differences of the weekly DREFonline solutions relative to the EPN solutions eurwwww7.crd

44 common stations (50%)

Example GPSweek 1960:

Differences are smaller than 2 mm Lat./ Lon. | 4 mm Up



DREFonline ⇔ EPN

- DREF online

Comparison EPN ⇔ DREFonline

```
=====================================
Bernese GNSS Software, Version 5.2

Program         : HELMR1
Purpose         : Helmert Transformation
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RESIDUALS IN LOCAL SYSTEM (NORTH, EAST, UP)
```

NUM	NAME	FLG	RESIDUALS IN MILLIMETERS		
1	AUBG 10913M001	I A	-0.04	-0.06	0.63
3	BADH 14288M001	I A	0.74	-0.18	-2.46
5	BOR1 12205M002	I A	-0.20	0.32	0.10
6	BORJ 14268M002	I A	-0.07	-0.02	-1.53
7	BRUX 13101M010	I W	0.20	0.13	0.21
8	BSCN 10028M007	I A	0.04	-0.29	0.56
9	BUDP 10101M003	I A	-0.04	-0.20	0.95
13	DIEP 14287M001	I A	-0.03	-0.09	-0.10
14	DILL 14286M001	I A	-0.05	0.39	1.10
16	ENTZ 10014M002	I A	0.04	0.05	-0.61
18	EUSK 14258M003	I A	0.07	-0.04	-0.75
24	GELL 10908M001	I A	0.14	0.08	-1.15
27	GOPE 11502M002	I A	0.04	0.19	-0.64
28	GOR2 14115M002	I A	0.34	-0.20	-0.63
30	GRAZ 11001M002	I A	0.20	0.27	-1.04
36	HEL2 14264M002	I A	-0.14	-0.08	-0.07
37	HELG 14264M001	I A	-0.21	0.24	-1.14
40	HOBU 14202M003	I A	0.28	-0.06	1.22
41	HOFJ 14289M001	I A	-0.11	-0.27	-1.72
45	KARL 14216M001	I A	-0.11	-0.08	0.69
46	KLOP 14214M002	I A	0.62	0.06	-1.31
47	KOS1 13504M005	I A	-0.16	-0.09	0.14
49	LDB2 14114M002	I A	-0.04	-0.12	0.14
50	LEIJ 14267M001	I A	-0.21	-0.05	0.08
		I A	-0.13	-0.43	-0.53
		I W	-0.20	-0.26	1.69
		I A	-0.14	0.14	0.03
		I W	0.07	-0.09	-0.84
		I A	-0.18	0.20	0.35
		I A	-0.11	-0.08	-0.32
		I A	0.10	0.43	0.78
		I A	-0.03	-0.02	1.24
		I A	0.14	-0.08	0.97
		I A	0.10	-0.20	-0.22
		I A	-0.02	-0.13	0.58
		I A	-0.29	-0.16	-0.09
		I A	-0.52	0.32	0.63
		I W	-0.10	0.03	-1.53
		I A	0.13	0.53	1.02
		I W	-0.06	0.06	2.59
		I W	-0.11	-0.23	0.97

	RMS / COMPONENT		0.22	0.21	1.03
	MEAN		-0.00	-0.00	-0.00
	MIN		-0.52	-0.43	-2.46
	MAX		0.74	0.53	2.59

```
NUMBER OF PARAMETERS   :      7
NUMBER OF COORDINATES  :    123
RMS OF TRANSFORMATION  :    0.63 MM
```

My Topics:

- Informations about our (precision) Control-Networks
- Definition of the (new) spatial reference frame in Germany
- First tests with Multi-GNSS, especially Galileo Observations and RINEX 3 in Bernese Software Vers. 5.2

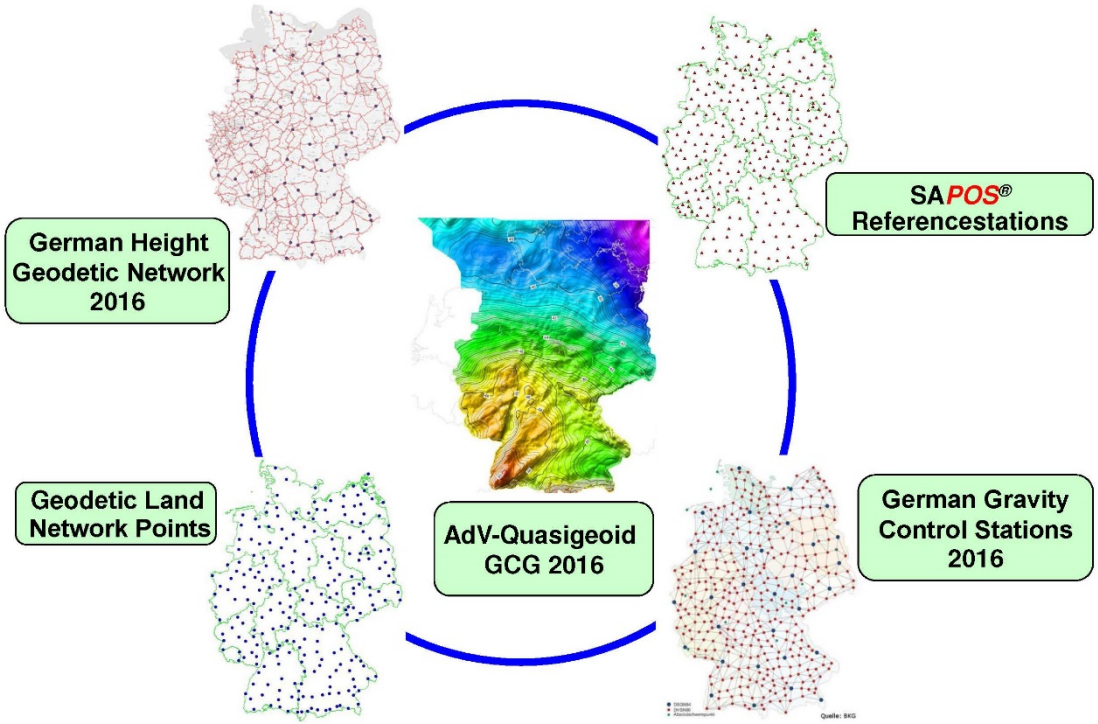
Spatial Reference Frame in GER

The **spatial reference of the official surveying and mapping** in Germany:

- the geodetic reference network points (ground marked, called “GGP”
- the 1st order height control stations,
- the gravity control stations of the gravity reference network
- the reference station points of the German state survey SA*POS*® satellite positioning service

All of this can be densified State-specifically.

Definition of the German spatial reference



→ **See also Sacher et al. - National Report of Germany, EUREF symposium 2016**

Spatial Reference Frame in GER

Realization of the new spatial reference in Germany DREF91 (R2016)

Adjustment of 600 stations, about 250 geodetic land network points (GGP) plus 272 GNSS reference stations of SA*POS*®, the GREF/BKG stations, 34 IGS/EPN and 44 stations of GNSS positioning systems of the neighboring states.

Observed together in June 2008 (4-week campaign)
2 Analyse Centers: BKG and LGN (Surveying agency of Niedersachsen)

Network datum: ITRF2005 coordinates of about 20 EPN stations at epoch of the campaign
Free network solution => transformed to ***EPN_A_ITRF2005_C1600***

Next steps:

- Transformation via Parameter of "Memo 7" to ETRS2000 (R05)
- Additional Transformation with 3 Rotations to DREF91(R2016)

Transformation of the old spatial reference, excluding stations with residuals greater than 10 mm in LON, LAT and 15 mm for the Up-component (=> 209 identical stations).

Why 3 extra Rot.parameter ? => No change in height for ETRS2000 => DREF91

Spatial Reference Frame in GER

This set of coordinates will be the new spatial reference frame in Germany, official established at 01. December 2016.

In reality some of the national federal agencies computed new coordinates for their GNSS reference stations because:

- a lot of antenna changes
- time between observ. in 2008 and establishment of final result end of 2016 is to long
- ETRF shift in UP component of about 1 mm/year

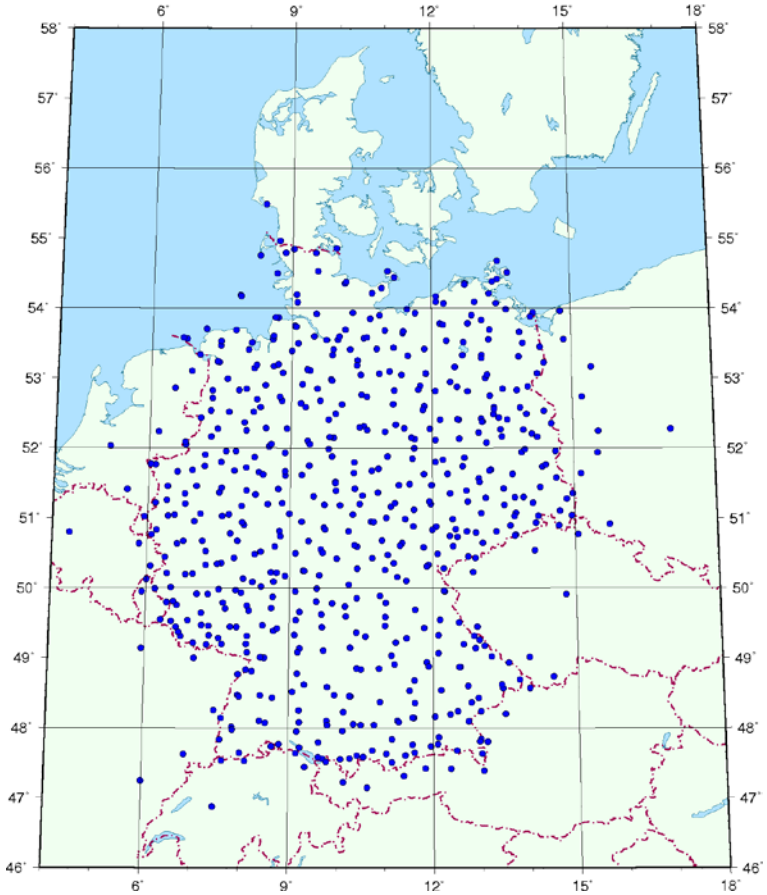
and some stations are removed / build up new. For this new stations coordinates in the spatial reference frame have been computed, mostly done by a local GNSS campaign including geodetic land network points.
(Guideline of the Working Committee of the Surveying Authorities of the Laender of the Federal Republic of Germany (AdV)

Next "release" is planned for 2020 ! (Observation-campaign 2020, result latest after 2 years !)

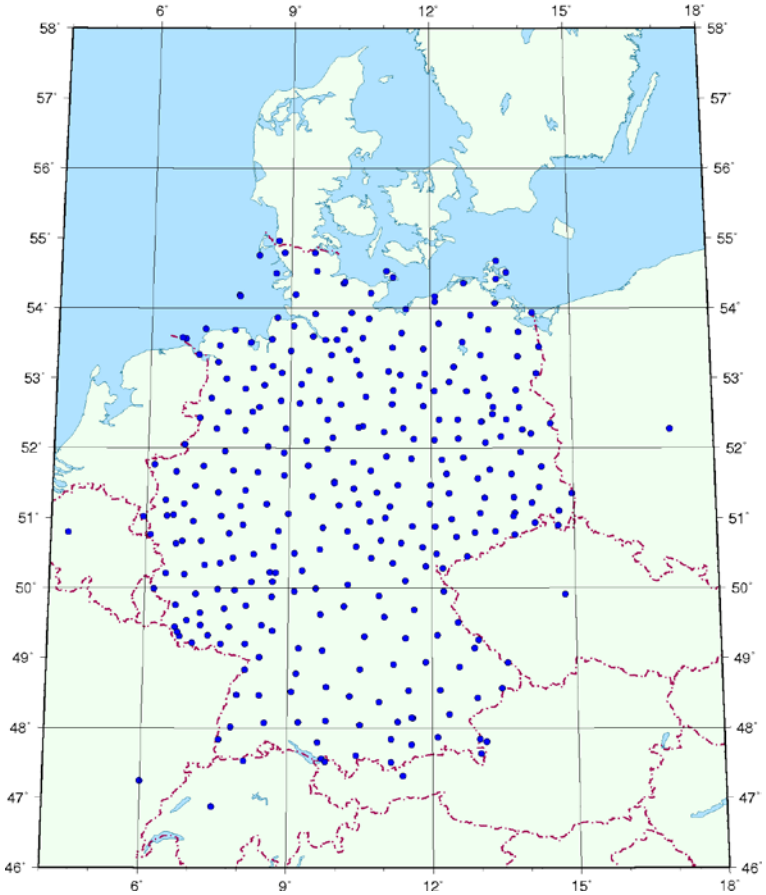
Actual controls daily/weekly: network adjustment plus transformation
IGS14/ITRF2014 => ITRF2008 => *(MemoV8)* ETRF2000(R08) => (3 Rot.) DREF91(R16)

Spatial Reference Frame in GER

All 600 stations of 2008 campaign



Only the GNSS stations



My Topics:

- Informations about our (precision) Control-Networks
- Definition of the (new) spatial reference frame in Germany
- First tests with Multi-GNSS, especially Galileo Observations and RINEX 3 in Bernese Software Vers. 5.2

RINEX 3 + GAL

- BKG-LAC / GREF **First tests with Multi-GNSS, especially Galileo**

Galileo in BKG-LAC / GREF / DREFonline

Input:
- Orbits: COM from AIUB, Mix RINEX 2 and 3 files
- PCV: Individual from EPN (epn_14.atx), type from IGS

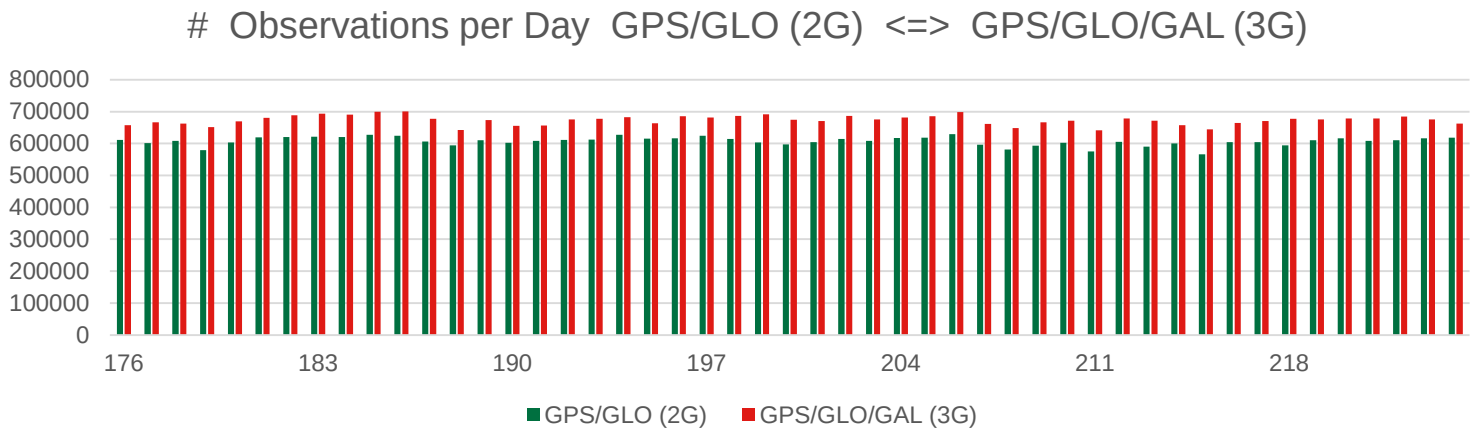
- BKG-LAC / GREF actual ~ 130 Stations
- 75 RINEX3 (57%), 67 files with new long filename
- 68 stations are tracking GAL (52 %)
- 12 stations are tracking GPS only

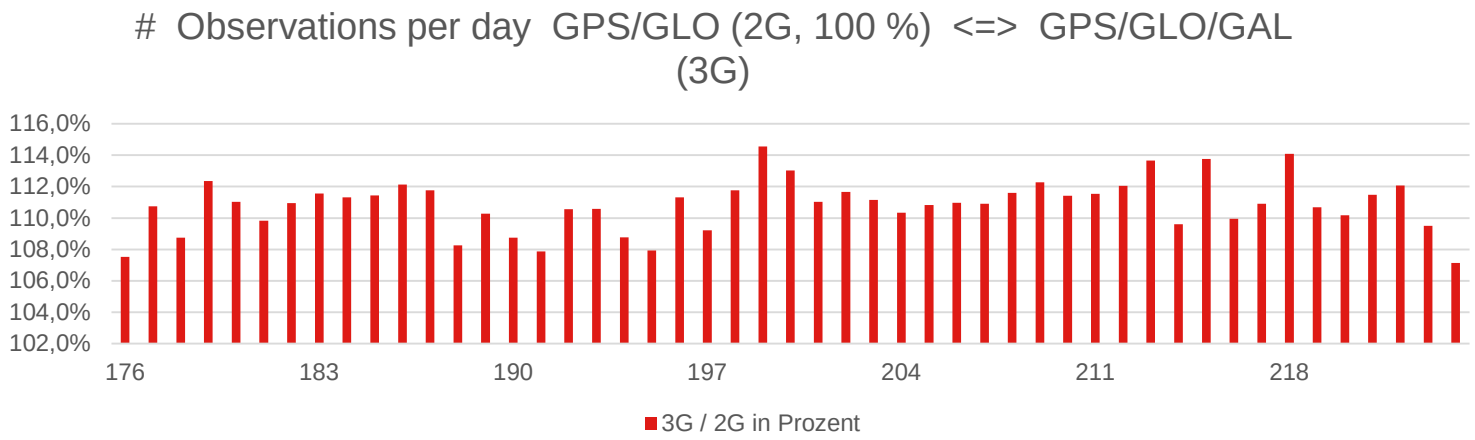
- DREFonline actual ~ 85 Stations
- 48 RINEX3 (57%), 38 files with new long filename
- 39 stations are tracking GAL (45 %)

Status of Galileo: Actually 15 Sat. are available

RINEX 3 + GAL

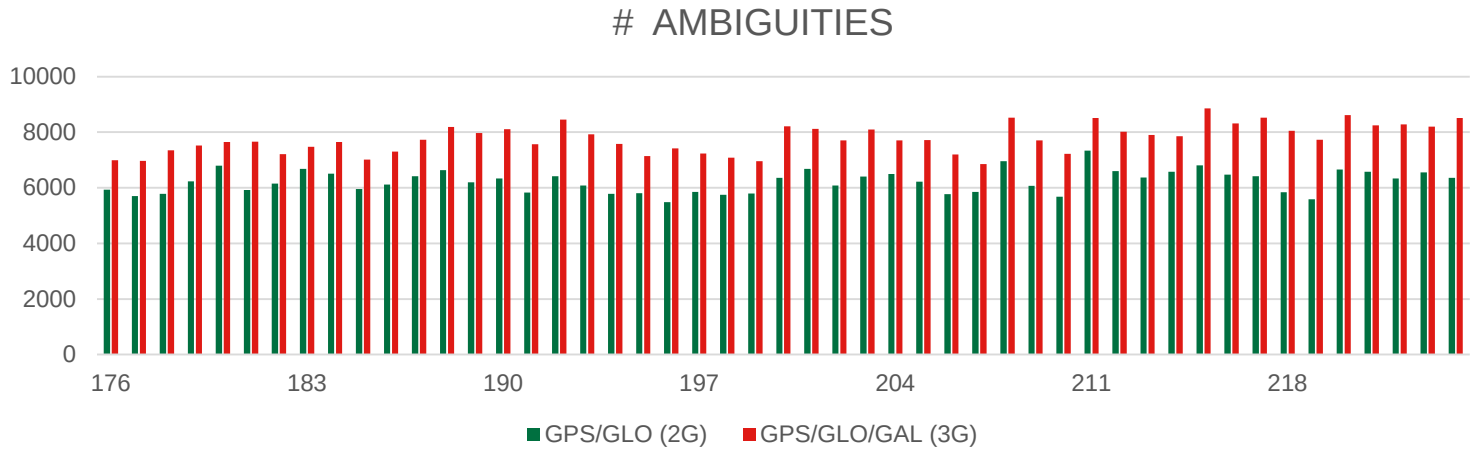
- DREF online

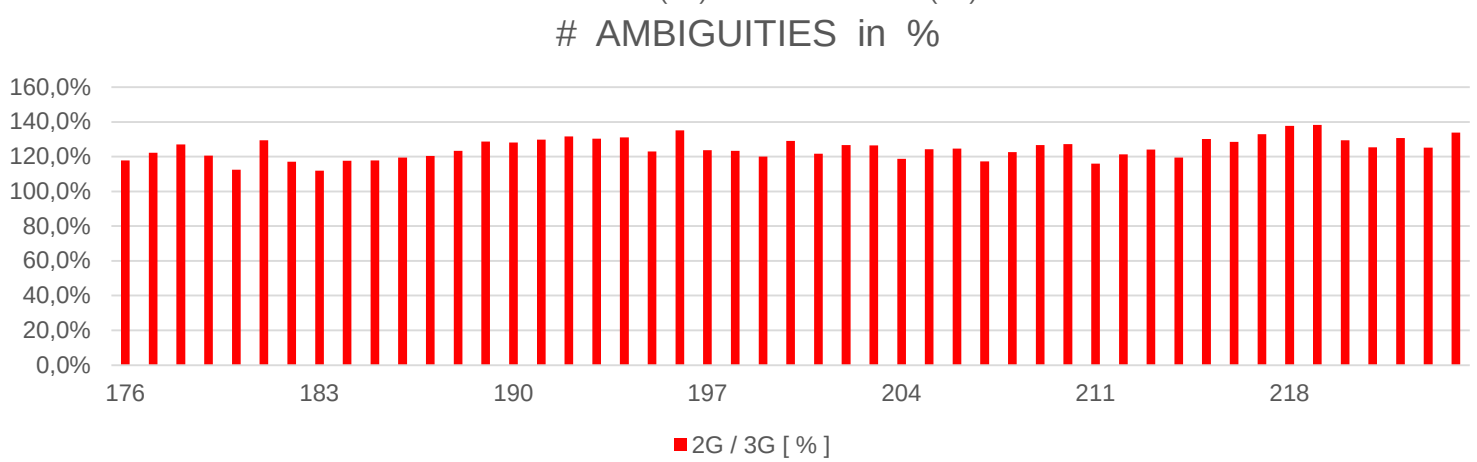




RINEX 3 + GAL

- DREF online





RINEX 3 + GAL

- DREF online

```
GALILEO SATELLITES :  38 of 85 Stations  (45 %)

AUBG |4434434444434444344423223224343444434444343344444433444444343444444344
BADH |5777666555666544544323223444545544555555544555456676655544556556555555
BOR1 |5556767655666445444322222233554544455554444445445454565554555555545554445
BORJ |587--7-----6- -54445434435--5---5----  -544566-5567-76555556665664556655
BRUX |5566677755666555544443223444344544555565544566455577655555466656655656555
BSCN |5355566656655444432222222222233344555444433334444442544445556665544334555
DIEP |4444434444334443444323333334344344443443444343444443343444444443444443444
DILL |4344444444434443443332222324343344434444343443344444433444444434344443444
ENTZ |5556566656666555544422222255534544455555544455445555565555456655565555555
ERLA |4434434444334443333322222324343444434444343323444443334444434434444443444
EUSK |4344444444434443444443222234343444434444444433444443434444444434344443444
FFMJ |577-777-56666-455444332324--54---5--5--5544566-5567866555455665565556655
GELL |4434434444434443444323223333344344443443444433444434343444434434444443444
GOET |6777777756666655544432333445455545555555544566455577665555555655565556655
GOR2 |4434434443434434444333333333234344443433444343444433344444434434444443444
HEL2 |4344344443434444444343443443344344443443444343444434434444443434444433444
HELG |6777777765-665-54445444435--54555-555---544556-5567-76555565665665565665
HOFJ |4434434444334443443322222223343444434443444344444443334444434434444443444
HOL2 |4434444443444433433223233323344344443443444343444433343444434434444433444
KARL |5676777--666--555444333234--5- -5--5-  -54456--455--65555555665565556655
KLOP |5656676656666455444433323433344544555555544464445446655454555565565554455
KOS1 |6877677-6-6----554454434346544--54555--5545566-55-- --5-5556665666566665
LDB2 |4434344443434443444222222233343444443443444343444434343444434434444443444
LEIJ |7778777665666554544443333 5--55--54-555-6544566-5567--65555555665665556655
OBE4 |5777677766666544433322223545545545555554544454445667665555555665565556555
POTS |5557677755666554333333433354555554555556444444555666665555555565555555355
RANT |677777776-6665-544454434344-545-5-555-66544566-5567676555555665665566565
REDU |5566666655665444444322222224343444555544334464444445655444455555554444555
SAS2 |6788877765665565444422334455555554555556444455656667666555555655545556455
SBG2 |5676666666666455434322222224554445555545543464444556665544555565555545655
TIT2 |5777777765666554544344333364545554555565544566455668665555556665565556655
WARN |6657677665665553344532 3435--5---5--5555644444--456--66555555655545556555
WRLG |5533455544454444333322222221112344445544333333222243332434445444444444333
WROC |4434344443434443444433333334343444444443444443444434343444434434444444344
WT21 |4434344443334443344322222244343444434444343343444443334444434434444444444
WTZR |4434344443334443444422223244343444434444343434444433344444434434444444444
WTZZ |5765666645555545444422223344545554 4-5-5443443355554454555455555545555455
ZIM2 |5665577656666545544422222254444545555555554455445546655554555565556554555
-----+-----------------+-----------------+-----------------+-----------------+
```

RINEX 3 + GAL

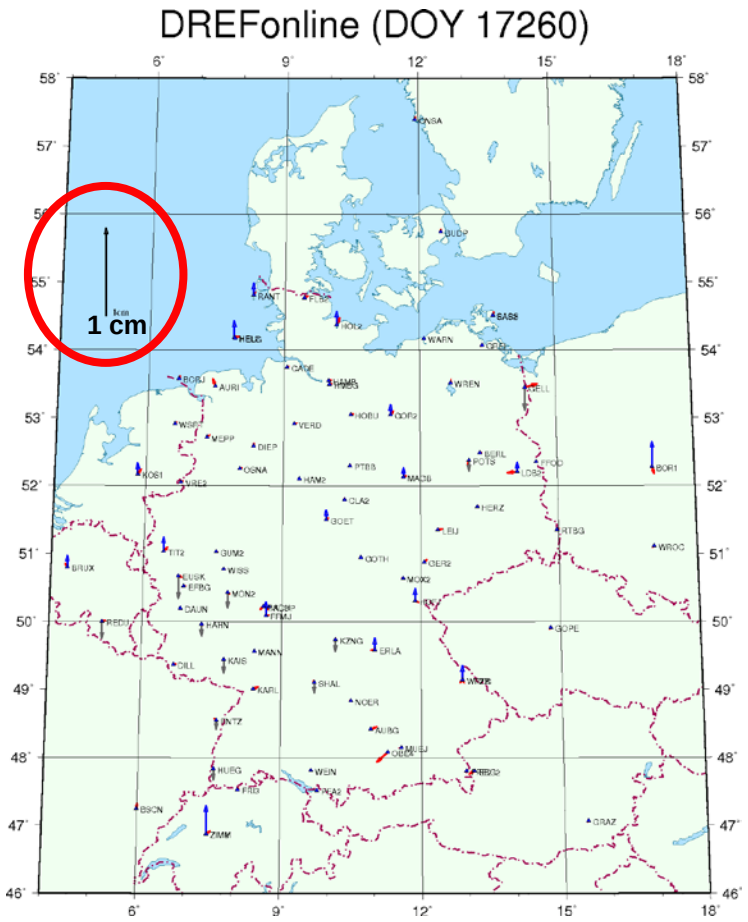
- DREF online

Comparison G3i ⇔ G2i

Daily solution
GPS/GLO/GAL ⇔ GPS/GLO

Example: Day 2017.260:

differences smaller than
2 mm Lat./ Lon. | 4 mm Up



RINEX 3 + GAL

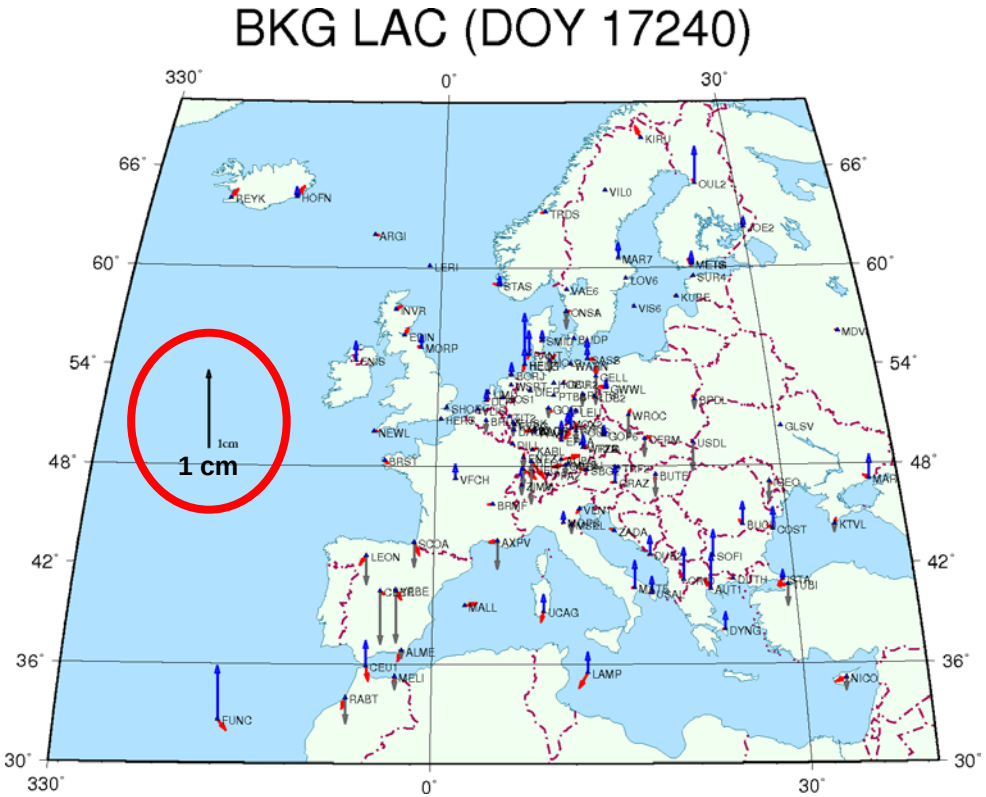
- GREF / BKG-LAC

Comparison G3i ⇔ G2i

Daily solution
GPS/GLO/GAL ⇔ GPS/GLO

Example: Day 2017.240:

differences smaller than
3 mm Lat./ Lon. | 8 mm Up



RINEX 3 + GAL

- DREF online

Influence of antenna calbibration

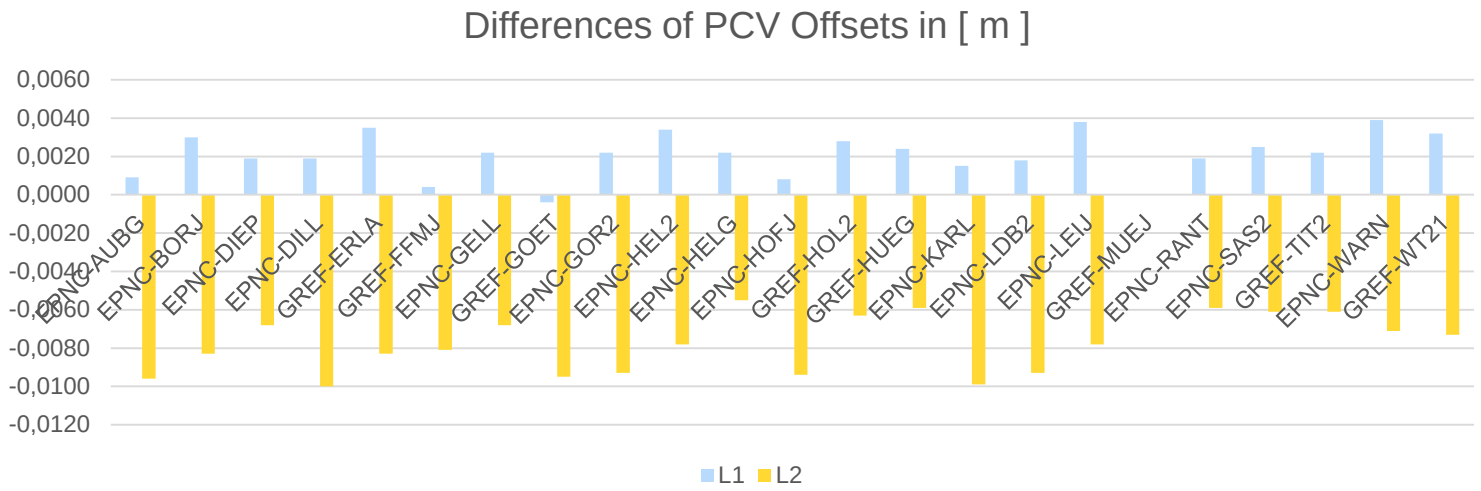
Roboter calibration (GEO++ or TU Berlin) ⇔ Chamber calibration Bonn

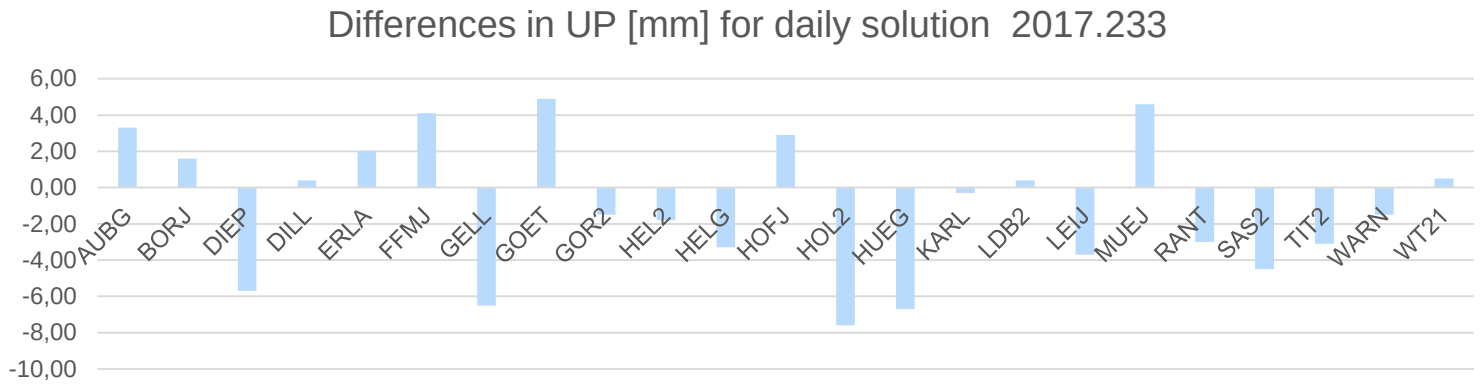
Roboter: Only GPS/GLO frequencies are calibrated (G01, G02, R01, R02)
for GAL values of GPS will be used

Chamber: Calibration for all frequencies
(G01, G02, G05, R01, R02, E01, E05, E06, E07, E08)

RINEX 3 + GAL

- DREF online





RINEX 3 + GAL

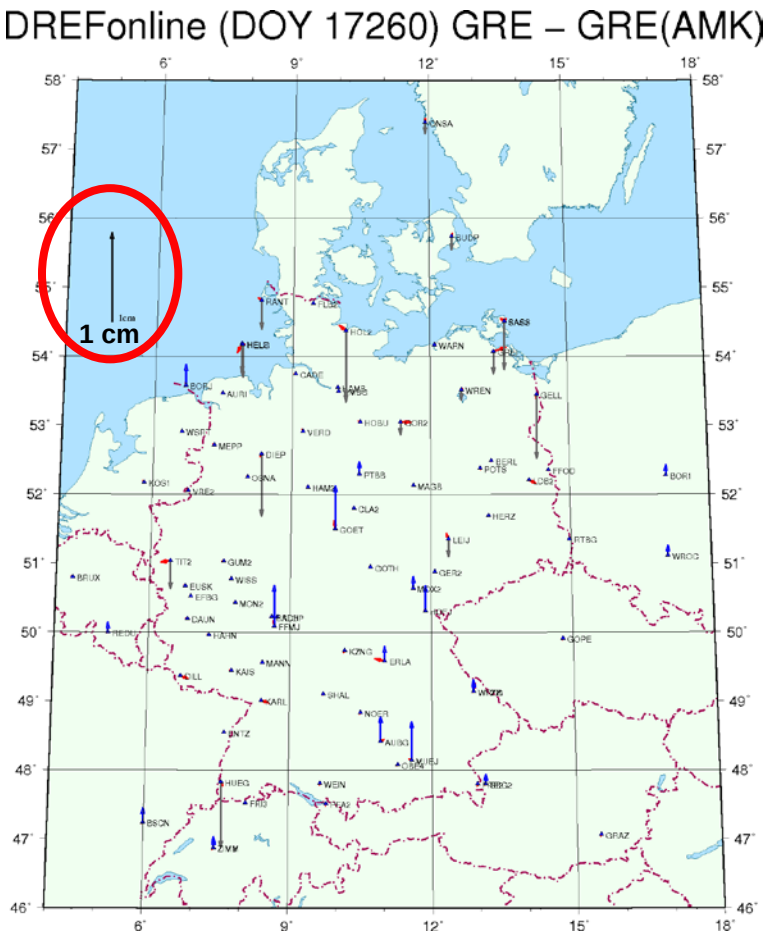
- DREF online

RINEX 3 + Galileo in DREFonline

GRE (GPS+GLO+GAL, RINEX3)

<=>

GRE (GPS+GLO+GAL, RINEX3)
(change of the individual Ant.-PCV)



Thank you for your kind attention!

Contact:

Federal Agency for Cartography and Geodesy
Section G2
Richard-Strauss-Allee 11
60598 Frankfurt, Germany

contact person
Peter Franke
peter.franke@bkg.bund.de
www.bkg.bund.de
Tel. +49 (0) 69 6333-279